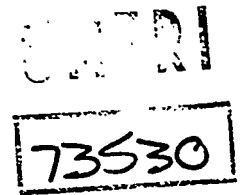


NSRP 0236  
NSRP-SPC-SP 4



DESIGN FOR PRODUCTION MANUAL

VOLUME 2 OF 3

DESIGN/PRODUCTION INTEGRATION

FINAL REPORT

PREPARED BY:

BETHLEHEM STEEL CORPORATION  
SPARROWS POINT YARD

AND

A&P APPLIEDORE LIMITED  
NEWCASTLE ENGLAND

AND

J. J. HENRY CO., INC.  
MOORESTOWN, NEW JERSEY

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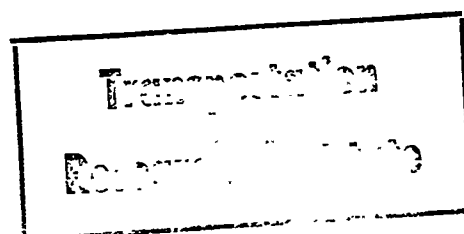
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NATIONAL SHIPBUILDING RESEARCH PROGRAM

BY

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS  
SHIP PRODUCTION COMMITTEE PANEL SP-4  
DESIGN PRODUCTION INTEGRATION

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## ENCLOSURE (1)

### FOREWORD

This manual is the final report of a project managed and cost shared by Newport News Shipbuilding for the National Shipbuilding Research Program under Maritime Administration contract DTMA91-82-C-20018.. The program is a cooperative effort of the Maritime Administration's Office of Advanced Ship Development and Technology and the United States shipbuilding industry. Industry direction was provided by the Society of Naval Architects and Marine Engineers' Ship Production Committee Panel SP-4, Design Production Integration.

Principle research was conducted by Bethlehem Steel Corporation, Sparrows Point Yard who enlisted the services of A&P Appledore" Limited, Newcastle-upon-Tyne, UK and J. J. Henry Company, Incorporated of Moorestown, New Jersey.

Project development demanded industry participation to insure that the manual respond to a need, that potential users were identified and that basic manual coverage was defined. Formal questionnaires were used in the early stages supplemented by telephone contacts and twelve face-to-face follow up meetings on the east, west and gulf coasts. As the need, potential user and basic content were confirmed, it became apparent that, for best results, industry should be involved in determining the manual structure and content. This was accomplished via development workshops on the east and west coasts and in the Great Lakes area. Forty eight individuals from 20 organizations participated. Shipyards from large to small were represented as were design agents and the Maritime Administration. Finally, to avoid duplication of effort and to benefit from as many responsible sources of input as reasonably possible, liaison was established with the Society of Naval Architects and Marine Engineers' Ship Design Committee.

Care has been taken to blend the needs, wants and advice of many into an orderly and authoritative work on efficient ship design and production. It is intended that users take advantage of the loose leaf format to make the manual even more useful by expanding it with their own implementing procedures.

## "The Design for Production Manual"

### An Executive Summary

Many, many years ago, some wise caveman invented the wheel. It is more than likely that the first wheel was delivered late and over budget! Some things in the past millions of years have not changed. Maybe it is new time for change.

The manual that follows this summary is not a re-invention of the wheel. Some of the ideas presented herein may strike a familiar note as you read through the manual. The developers of the manual attempted to collect and assemble a multitude of ideas and techniques involved with shipbuilding; all having the common directive of Design/Production Integration. Their intent, however, was not only to collect these ideas but to also present them in such a manner as to assist you and your organization in a re-thinking process concerning shipbuilding design and production.

To this end, the writers want to emphasize that this manual is not a common cure for all of the U.S. Shipbuilding Industry's woes. It is merely presented to you as, hopefully, the catalyst to initiate the required re-thinking process and to give some information to you concerning the most effective starting points as to where this re-thinking effort should be directed.

The most logical way to summarize a piece of work having the magnitude of the manual is to try to clearly define its title "Design for Production". A possible definition of the manual and its objective could be "Designing to reduce production costs to a minimum, compatible with the requirements of the vessel to fulfill its intended function with acceptable reliability and efficiency!". It is readily ascertainable that this definition protects the interests of the shipowner but also states the desired interests of the shipbuilder. Historically, the shipowner was primarily interested in those aspects of his vessel that most affected his dollar. Items such as vessel speed, fuel consumption, cargo carrying and handling capabilities and mission requirements were paramount in the owner's thinking. A private design agent would be hired to protect the owner's interests as listed above and the design developed around these interests led to an expensive, difficult to build, but functionally correct vessel. By the time the shipbuilder received the design, he would find himself tied to a design, more often than not, totally unsuitable for the production personnel, techniques and facilities available at the building yard.

It is apparent, or it should definitely be apparent, that high productivity shipbuilding is critically dependent on the effectiveness of the relationship between the shipbuilder and the ship designer. Their intertwined efforts should constantly strive to optimize the design processes, planning processes, production techniques and facilities available.



Ever so slowly, the situation is changing. There have been advances in construction techniques and shipbuilding facilities have been modernized. However, vessels are still being designed that do not utilize effectively these new techniques and facilities. This is the underlying problem. The design function is still ignorant of the needs of production and the production function is not knowledgeable of the design process. Shipyards are designing vessels around the use of pre-outfitted modules but ignoring the building basin crane capacity to lift the completed modules. Units are being designed utilizing plates of a given length ignoring the fact that the panel shop can operate more efficiently using plates of another length. Both of these examples must sound very academic; however, as shipbuilders and designers, we know that these types of design problems do, in fact, take place in our shipbuilding world.

Again recalling the definition of "Design for Production" given earlier and realizing that problems as described in the previous paragraph do take place, we, as members of the domestic shipbuilding industry should remember that the uppermost objective of the shipbuilder should be ". . . . to reduce production costs . . .". This is where our profits come from and also where they are lost.

The expansion of the design process to include a "Design for Production" function should have as **its** foremost objectives:

To produce a design which represents an acceptable compromise between the needs of a shipowner and a shipbuilder.  
(Functionability versus Producibility)

To produce a design which has features compatible with known characteristics of the shipyard's facilities. (Availability versus Producibility)

To produce a design which facilitates the integration of the outfitting effort with the structural steel fabrication and assembly effort. (Integrability versus Producibility)

For all of this to work, the designer has to be familiar with production and the producer has to be familiar with the design function. To state the obvious, it will not be possible to achieve short delivery times and high productivity levels unless design and production work "hand in hand". After review of the manual, you will see that this idea is the common thread throughout the manual.

All U.S. shipyards are, in some fashion, moving along the Design/Production Integration Highway. Some have gone far and done well while others have stalled. The objective of the manual is to clearly show the way forward. The road is long and does have hazards but the final destination is clearly defined. That final goal is a vigorous and competitive U.S. Shipbuilding Industry.

VOLUME 2

DESIGN/PRODUCTION INFORMATION

PART 1

REQUIREMENTS

## VOLUME 2 - DESIGN/PRODUCTION INTEGRATION

### SYNOPSIS OF EACH PART

#### PART 1 - REQUIREMENTS

Volume 1 of this manual introduces the topic of design for production, and outlines the changes in shipbuilding which have led to a need for greater integration between design and production.

In this part, some of the requirements of that integration are introduced. Primarily, the emphasis is on the need to formalize the communication system between design and production. Ship cost can be considerably influenced by integration, but in order to achieve this, it is essential for the design function to have a clear, documented definition of the production system. The designer must respond to this information by developing his design in a manner which reflects both the physical requirements and the timescale of production.

#### PART 2 - SHIP DESIGN STAGES

The design of a ship is an iterative process in which approximations made in the early stages are continually improved and expanded as a consequence of late work. This design work is carried out in a series of stages traditionally called the design spiral.

Each new design stage provides an increased level of detail over the stage preceding it, leading iteratively to the final design and eventually to the actual ship construction. While in practice the distinction between the precise content of each individual stage may vary (depending on the perceived needs of the owner, similarities with existing ships, special requirements of the regulatory agency involved and so on) the overall sequence of these stages remains the same.

As the nature of the design stages are delineated, it is important to note opportunities early on to introduce more effective producibility concepts. Good design must lead to sufficient production. Simply put, ship construction involves hull structure and outfitting. The effective interrelationship of these two aspects during the actual construction process is critical to an efficient and cost effective construction plan.

The four stages of development within the design spiral are:

conceptual design,  
contract design,  
functional design,  
detail design.

A fifth stage, transition design, can also be identified. This translates the emphasis of the work from the function of the vessel to its construction. It is primarily a stage which lies between functional and detail design.

This part of the manual examines each of the five stages from a production viewpoint. In addition, two specific design topics are addressed which impact design for production. These are CAD/CAM and the format of engineering information.

### PART 3 - SHIP PRODUCTION

This part of the manual discusses how information should be collected and presented to be available for use by designers and is presented here to give designers a basic knowledge of ship production methods and facilities. The first chapter describes modern production technology and indicates the important features relevant to the design. The second chapter provides guidelines for facility documentation, the information that should be recorded and regularly updated for input to the design process at all levels. The third chapter provides the same information for production processes and methods.

A vital aspect of design/production integration is feedback. If designers learn about production problems and a dialogue exists between design, production engineering and production, then the means to achieve change is available. The final chapter of this part describes the feedback system.

### PART 4 - PLANNING

This part of the manual gives a broad outline of the scope and activity of the planning function. The first chapter considers the organization of planning and describes the three planning levels - strategic or long term planning, tactical or medium term planning and detail or short term planning.

In the remaining chapters, each planning level is described in more detail. Flow charts showing the principal information flows and interfaces with other functions are provided.

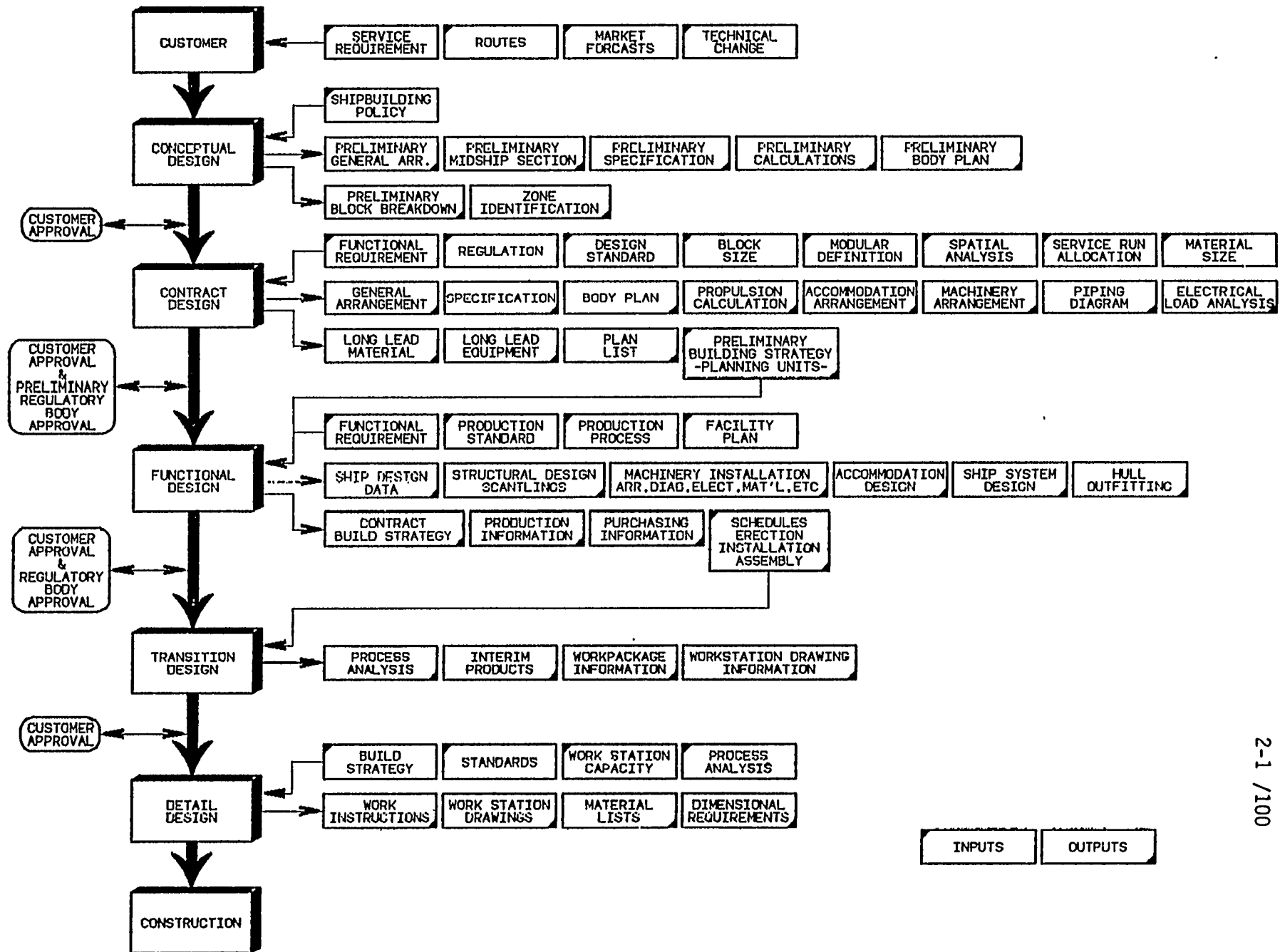
The planning structure and system outlined here is based on the premise that simple production requires simple planning.

2.1 REQUIREMENTS

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# Design for Production - Design Stages



### 2.1.1 SHIP COST - INFLUENCE ACCORDING TO DESIGN STAGE

The design of a vessel has a significant effect on the cost of production. This is primarily a function of the work content built into the design, but to some extent the cost is influenced by how closely the design is aligned with a particular set of production facilities. The influence declines as the design progresses. At the conceptual design stage work content can be minimized by attention to production requirements. By the detail design stage, the opportunity left for improvement is small.

#### CROSS-REFERENCES

- 2.1.2      Producibility Objectives
- 2.2        Ship Design Stages
- 2.3        Ship Production



### 2.1.1.1 Cost Reductions

Ship cost is a function of labor, materials and overhead. From the perspective of design for production, a reduction *in* ship cost *is* sought by a reduction in the direct manhours by making the vessel easier to produce. This will be the main theme of this chapter. Further cost reduction can be achieved:

in overhead, by shortening the cycle time to build a ship,

in materials, by standardization.

Direct labor cost is directly related to hours used. The hours used are a function of three main components:

work content caused by design,

productivity achievable with the available production system,

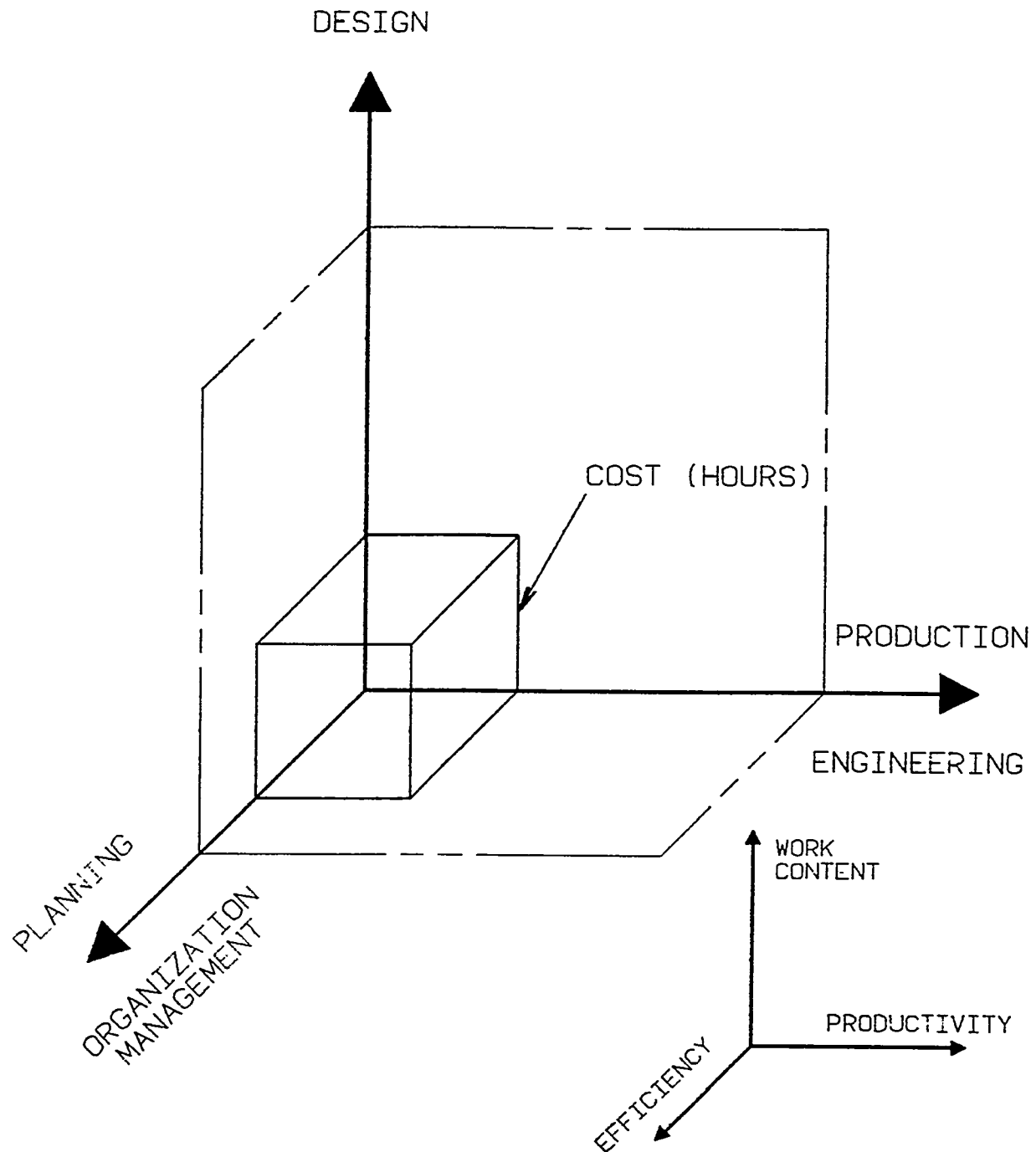
efficiency, defined as productivity achieved compared with that which is possible.

The figure (page 2-1/103) shows the relationship between the three components. To minimize the hours taken to produce a vessel, all three must be considered.

Efficiency is dependent upon management - how good is planning and material control; and on labor - how much time is spent working. These aspects are generally outside the scope of this manual.

The work content of a vessel is directly affected by the design process. The design should not only seek to minimize work content, but also to integrate design and production so that the potential productivity is improved. The opportunity to achieve this integration is dependent on consideration of production at an early stage of the design process.

$$\text{WORK} \times \text{COST/UNIT} = \text{COST}$$



THE COMBINATION OF DESIGN & PRODUCTION ENGINEERING  
REDUCES THE WORK WHICH THE ORGANIZATION HAS TO  
CARRY OUT.

### 2.1.1.2 Work Content

The work content which arises from a design is not inherent in that design. It does not derive from any simple parameter (for example weight or dimensions). Work content is susceptible to analysis and to deliberate change.

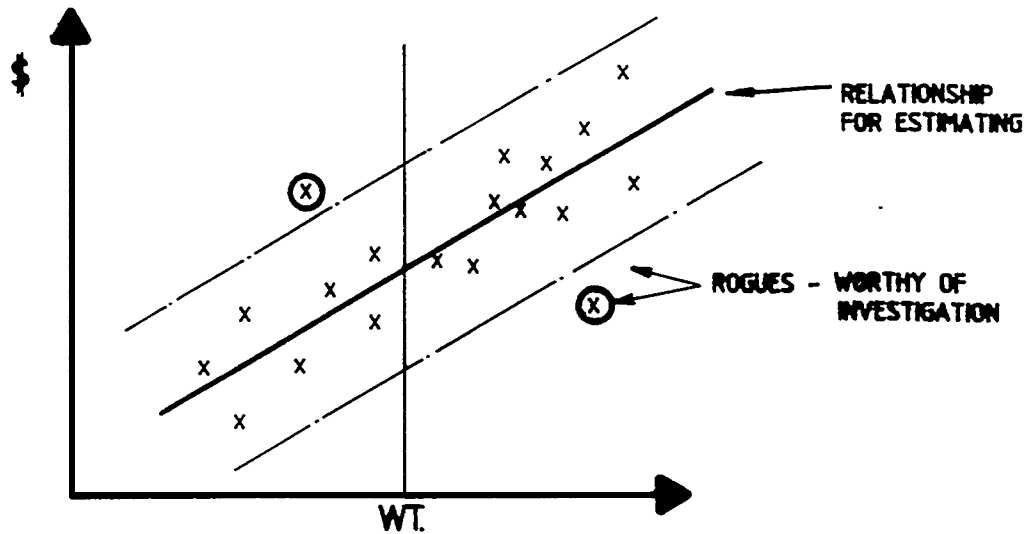
Steel weight or another parameter can be plotted, as in the figure, against work content for a range of vessels. Dependent on the similarity of vessel type, and the similarity of design and production processes, a relationship of use for estimating purposes can be derived. However, this is a very simple model and, except in broad terms, it is dangerous to deduce that weight and cost have a direct relationship. Rather, there is a broad band of work content into which similar vessels of equal weight will fall. Those vessels which fall outside the band - rogues - should be investigated to determine what lessons can be learned.

The variation in work content for a given steel weight can be explained by the variation in design for production. Considerable improvement can be achieved without a weight penalty, and any small penalty can be offset by reduced work content.

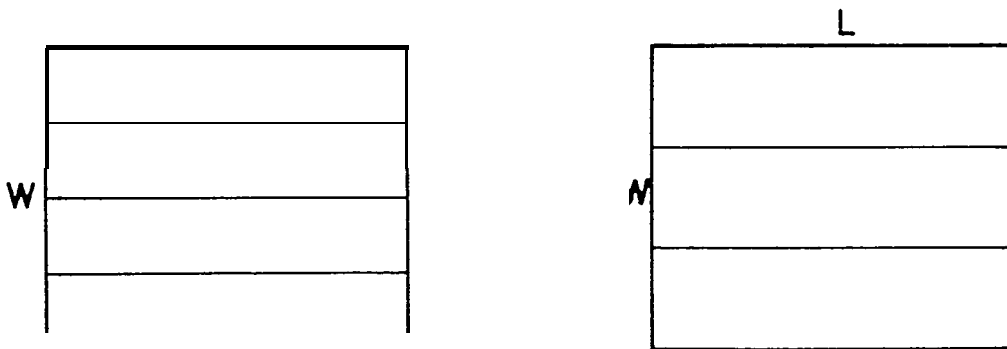
That work content can be varied without a weight change, is demonstrated simply by considering the effect of changing plate size within a panel structure, or pipe configuration within a pipe run. In the case of a plate panel, the butt welding length can be reduced by using wider plates. In addition to welding, the costs of material handling and plate cutting can be reduced. However, the production facility must be able to handle the wider plate.

The ability to influence work content through design is considerable, but the level of influence varies dramatically as the design process progresses.

At the conceptual and contract stages the influence is at its largest. Thereafter it declines as the design is progressively "hardened". At the same time the cost influence declines as the **producibility input is increasingly offset by the cost of design** changes. Decisions taken at each stage can the incorporation of producibility at subsequent stages.



FOR A GIVEN WEIGHT (L, GRT) FOR A TYPE THERE  
WILL BE A RANGE OF COSTS, WHICH WILL BE CONSISTENT  
FOR A SHIPYARD OR DESIGN TEAM



BY VARYING PLATE WIDTH, THE WORK  
CONTENT OF TWO OTHERWISE IDENTICAL PLATE  
PANELS IS REDUCED FROM 3L TO 2L FEET OF  
BUTT WELDING

### 2.1.1.3 Influence at Various Design Stages

As - previously stated, cost can be influenced at each stage of design, but the degree of influence decreases as more of the design becomes fixed.

The curve opposite shows how the degree of influence may vary. It is not quantitative, but shows the influence moving from a maximum to a minimum level over the timescale of a design. The actual degree of influence would depend on the particular circumstances of a contract and on the progress already made by the design team in design for production.

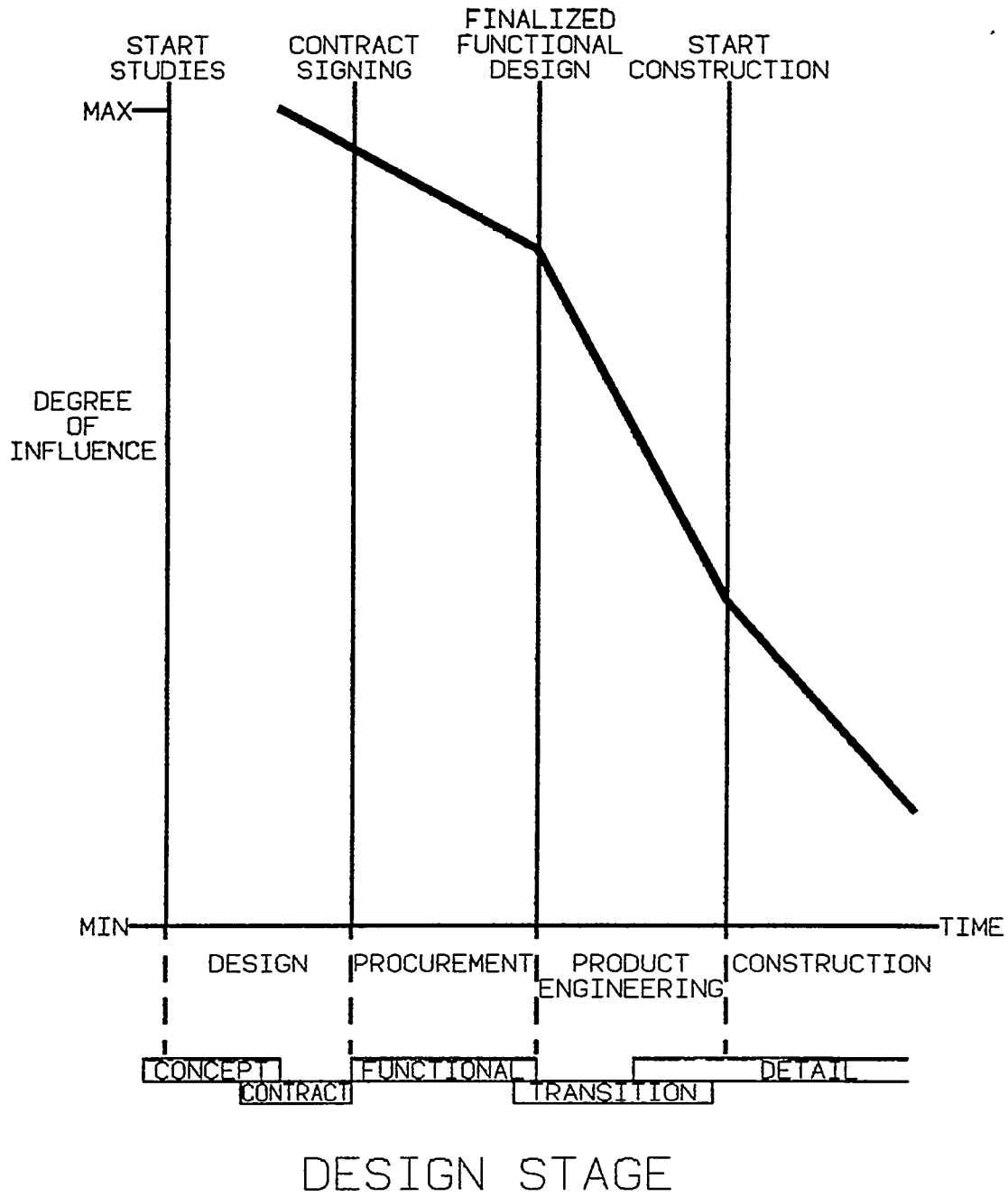
Overall, the shape of the curve indicates what would be expected, in that the degree of influence remains high until the start of transition design. Thereafter, as the location of systems is finalized, the influence declines rapidly.

At the conceptual design stage, by selecting key dimensions and arrangements which correspond to shipyard preferred material sizes and unit dimensions, the total steel joint length and the number of units can be reduced. In addition to a reduction in absolute work content, a potentially shorter build cycle time may be possible. The potential use of standard layouts can be identified.

At the contract design stage engine room and other functional space layouts can be based on standards. The optimal location of equipment and auxiliaries, grouped by function, minimizes the connections which generate the bulk of on-board installation work content. Preliminary process analysis incorporates producibility into the midship section.

During functional design process analysis for each planning unit simplifies connections and increases standardization as the structural plans are developed. The work content reduction is small, but the necessary work content can be closely matched to the production processes which are available. The effect is on the productivity of the shipyard, rather than on absolute work content.

# INFLUENCE ON COST



Transition design develops the functional design into a format which suits production. Service runs distributive systems are allocated to predefine functional spaces. work is transferred to an earlier stage of the production process (via outfit assemblies, for example). Opportunities for standardization are created. The emphasis is on increasing the potential productivity, rather than reducing work content, because of decisions taken at earlier stages.

At detail design, with the main features of the design fixed, only minor variations can be achieved. However the maximum use can be made of standard details.

### 2.1.2 PRODUCIBILITY OBJECTIVES

The overall objective of a business is profit. A hierarchy of objectives can be built up to support this overall objective. One of the key elements for a shipbuilding company is producibility. The two objectives of producibility are to reduce work content and to reduce the build cycle time for a vessel. These objectives can be achieved through design for production, which is not in conflict with design for operation but is another dimension of the total design process. The improved producibility also enhances the overall quality of the final delivered product.

#### CROSS-REFERENCES

2.1.1 Ship Cost - Influence According to Design Stage

2.2 Ship Design Stages



### 2.1.2.1 Overall Context

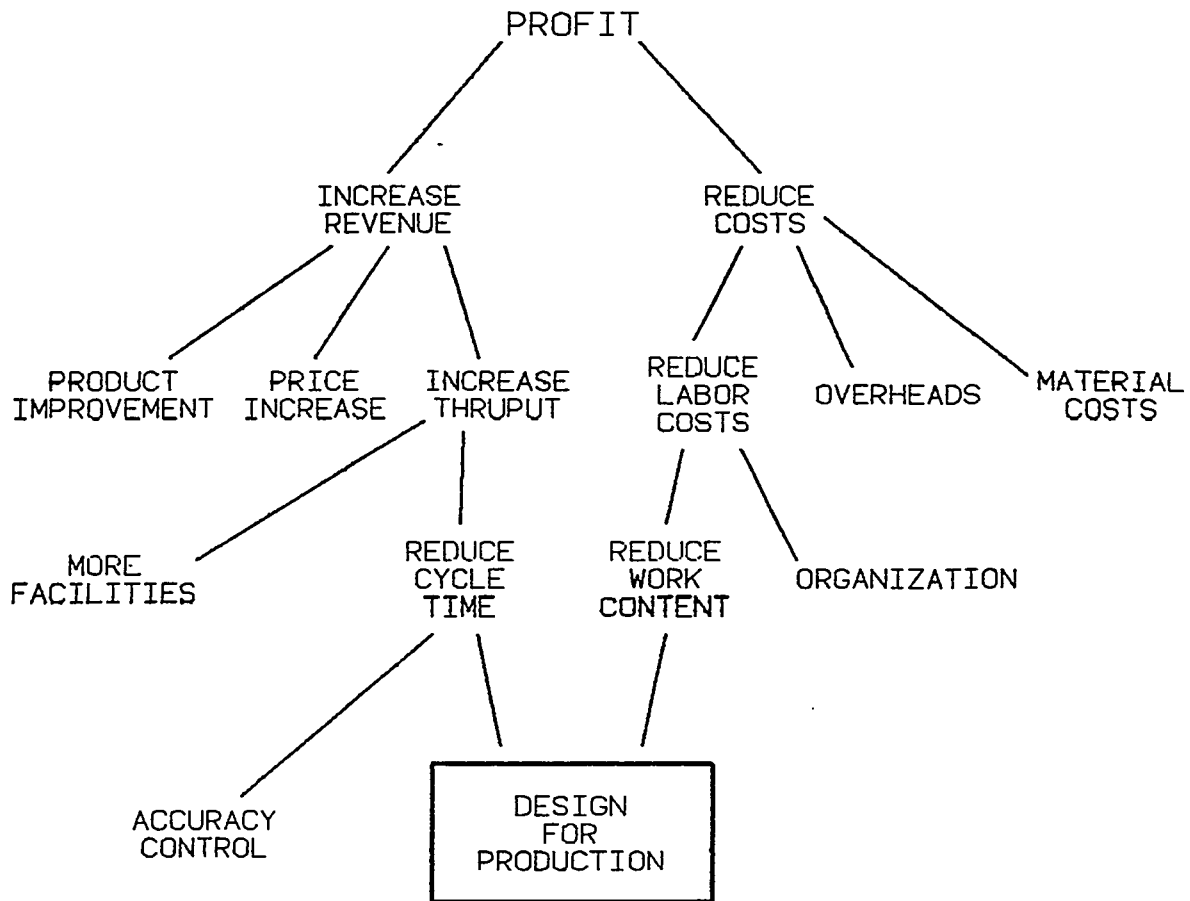
This manual is intended to show how producibility can be improved. It is important to see how the need for producibility fits inot the overall objectives of a shipbuilding company, and to see what gains improved producibility can attain.

The overall corporate objective is ultimately survival and profit. The means to achieve this are cost reduction and revenue increase. These are not alternatives, but two elements of a single policy. The emphasis will switch from one to another with changes in the company operating environment.

**Cost** reduction and revenue increase themselves become lower level **objectives** for which means can be found. A hierarchy of objectives can be built up in which the means at each level become the objectives of the next lower level. **This** is illustrated in the figure opposite. Thus corporate objectives require actions which become divisional objectives; these lead to departmental objectives, and so on.

Increased revenue can be achieved by price increases and by developing more sophisticated products. However, the most important means is to increase the number of vessels built. Again, the operating environment may restrain one or more of these. To reduce cost, cuts can be made in material specifications, in labor cost and in overhead. One of the means is the improvement of labor productivity.

The increasing of throughput and reduction of work content can be achieved by capital investment - in extra berths, larger cranes **and** automation of work stations. However, these may conflict with other objectives, in particular the reduction of overhead. One means of achieving both a reduce work content and a reduced cycle time is design for production; that is, to improve producibility.



- EACH LEVEL IS OBJECTIVE FOR LOWER LEVEL
- EACH LEVEL IS MEANS TO ACHIEVE HIGHER LEVEL OBJECTIVE

#### 2.1.2.2 Productibility Objectives

The two specific objectives of design for production are:

- to reduce the work content of a vessel,
- to reduce the construction cycle time.

The former addresses direct cost, the reduction of labor hours necessary to complete work. The latter addresses indirect cost, the spreading of overhead over a larger number of vessels. Both objectives will fit into a hierarchy of corporate objectives and means.

Aside from the achievement of these two main objectives, a number of other benefits will naturally be realized with the introduction of design for production. These include:

- improved quality,
- improved working environment,
- better material utilization,
- improved productivity.

### 2.1.2.3 Achieving Producibility Objectives

Achieving the two objectives requires a considerable change in the design function, supported by a clear definition of needs by the production function. The work content can be designed out in several ways, for example:

designing simpler structures with fewer pieces,  
using maximum material sizes,  
standardizing components.

Care has to be taken when pursuing the objective of reducing the number of pieces. The drive to reduce the number of pieces may lead to detailed design features that require very high degrees of accuracy in fit up. If the shipyard can consistently achieve the required levels of accuracy and fit up problems do not arise at the assembly stages, then the drive to reduce pieces has not prejudiced the overall objective of achieving the required rates of output. For those yards that cannot achieve the required levels of accuracy, alternative detail design features must be considered that may result in an increase in the number of pieces but allow consistency of assembly time to be achieved.

The build cycle can be reduced by:

reducing the number of planning units,

designing the vessel as a hierarchy of assemblies, which allows work to be carried out simultaneously in several locations away from the building berth.

Reducing the number of planning units, for steelwork, implies building units to the maximum berth crane capacity. This in itself is desirable; however, consideration must be given to the configurations of the units such that they are self-supporting, thus requiring less crane time for erection. Other factors such as access for open sky outfit and the need to create planning units of as near equal size, weight and work content as possible must also be considered.

The means of achieving the two main objectives also lead to the additional benefits.

Productivity Improvement can be achieved by:

- matching products to available processes (for example, ensuring that the choice of a welded or flanged face flat is made on the basis of preferred shipyard practice),

- standardizing components,

- designing connections for easy fit-up,

Quality can be improved through:

- standardization,

- moving work from berth to workshop, by designing assemblies.

Environment can be improved through:

- more work in workshops as opposed to outside,

- better orientation (downhand working where appropriate).

- safer access to work

- safer and easier materials handling

Material utilization can be improved through:

- standardization, for example, standard pipes or brackets can be produced from appropriately sized raw material with minimum waste.

#### **2.1.2.4 Design Objectives**

The overall objective of the ship designer is to produce a vessel which will perform to specification at minimum cost. This economic-oriented view of designers expressed by the concept of the design spiral. Successive iterations go into greater detail following the same sequence of events. Each turn of the spiral can be regarded as corresponding to one of the design stages discussed in Part 2 of this Volume:

conceptual ,  
contract,  
functional ,  
transition,  
detail.

Within this process, ship first cost is considered based on estimating procedures. While conventional procedures give an adequate estimate, they are based on historical data and do not consider positive action taken to improve producibility. The cost of a vessel is not simply a function of past data, but can be strongly influenced at the various design stages.

The optimization process, expressed by the design spiral, does not lead to a single, ideal result. Rather, because of the interaction of conflicting objectives, it leads to a range, within which the designer has freedom to exercise judgement. It must be clear that introducing producibility as an objective is not in conflict with the fundamental objectives of design. Rather, it requires the choice of the most producible option from a range available to the designer which will meet the vessel mission requirements.

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### 2.1.3 DESIGN FOR REPAIR/OVERHAUL/MAINTENANCE

In addition to its specified mission requirements, a ship must have in its design provision for repair, overhaul and maintenance. These require access spaces, withdrawal routes and allowance for additional equipment to be built into the vessel.

The structured approach to design which is presented in this manual, based on spatial analysis, allows these additional space requirements to be explicitly stated. Design for production and design for function can be made compatible.

### CROSS-REFERENCES

#### 3.1.6 Process and Spatial Analysis



### 2.1.3.1 Design for Function

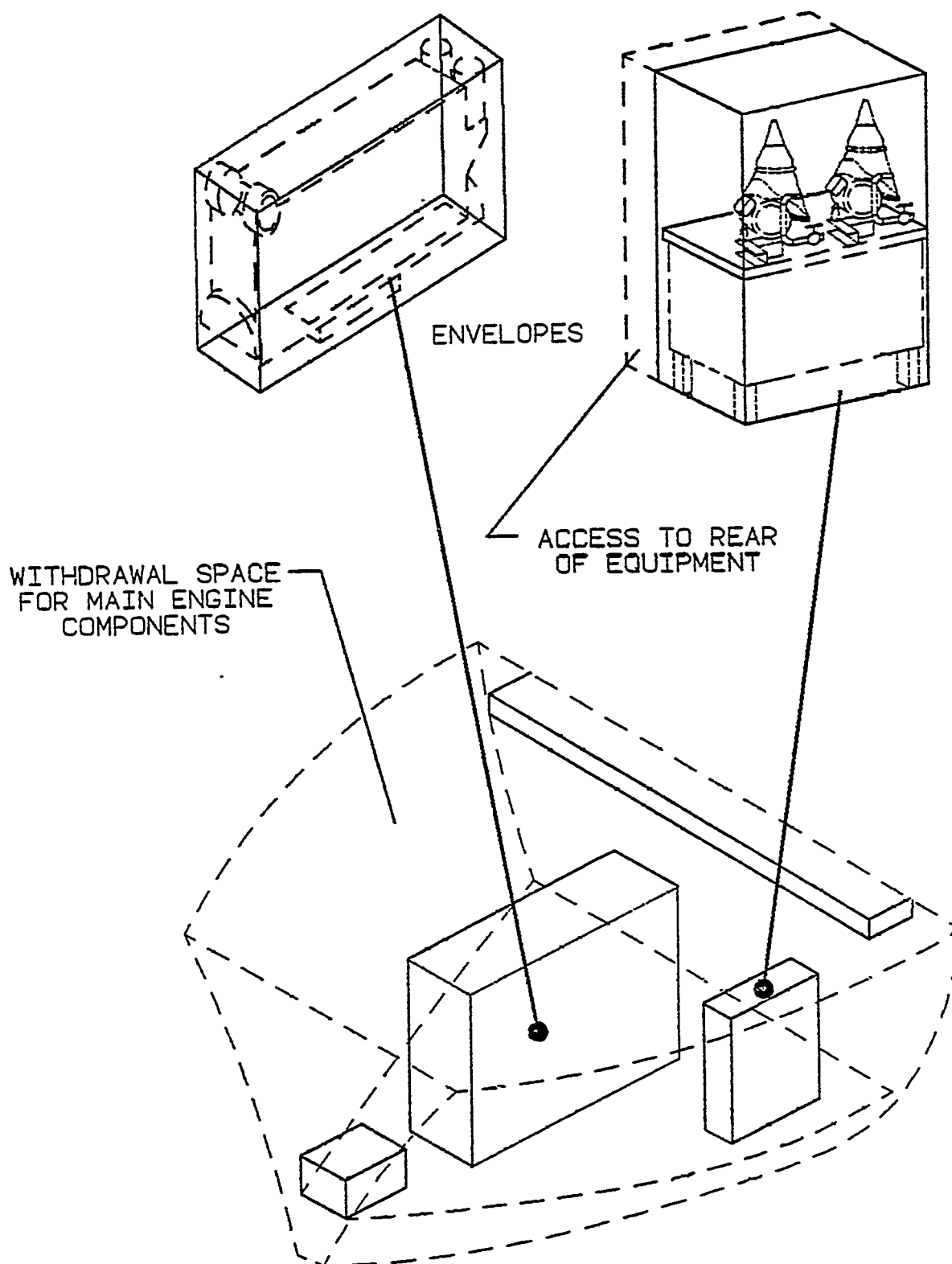
The objective of the ship designer must be to create a vessel which will perform certain functions. It must operate as specified by the shipowner, for example.

travel at a given speed,  
operate at a given fuel consumption,  
carry a given amount of cargo,  
meet classification and other regulations.

Within the lifetime of the vessel, it is inevitable that some of the sub-systems will require to be replaced and their replacement may even be planned from the initial phase. Additions to the vessel may be made. Further, many of the systems will require routine maintenance during their lifetime. Finally, there is also the possibility of damage during the vessel's lifetime.

In designing for function, all of these additional considerations must be taken into account. In the context of Design for Production, the question must be asked as to what impact a production-oriented approach will have on the various functional requirements specified.

The structured approach to design which is proposed in this manual is compatible with the functional design requirements. How the various requirements for repair, overhaul and maintenance can be built into the design process is the subject of the rest of this chapter. The figure shows the incorporation of access spaces into a design.



### 2.1.3.2 Design for Maintenance

It is necessary to specify the requirements imposed on the designer by maintenance considerations. In practice these are primarily related to access:

for people; to be able to reach all necessary locations, and to carry out maintenance functions.

for tools; any specialized equipment for maintenance must be able to reach the appropriate location and be operated.

for ship equipment; where maintenance is by replacement, adequate space must be provided to withdraw equipment, including space for lifting appliances and means of transport.

Each of these requirements can be expressed in terms of an envelope, that is a necessary volume. In the design procedures proposed in this manual, the envelope approach is utilized for the preliminary definition of each functional space of the vessel.

The envelope for any space is defined so as to be able to include all the necessary equipment from any one of a number of potential suppliers. The requirements for maintenance access must be included in the functional space envelope.

At the functional design stage, the envelope for each functional space is described, but not the internal configuration. The envelope is based on standards, on past practice and on known requirements.

At the detail design stage, the internal arrangement of the space is confirmed and production information developed. Sufficiency of access for maintenance purposes will be checked at this stage and incorporated in the space design.

### 2.1.3.3 Design for Repair and Overhaul

**During** the lifetime of a vessel, one or more major overhauls may be required, or it may be necessary to replace, update or add to the ship's equipment. Requirements for these functions are:

access for people and equipment.

withdrawal space for equipment and a route out of the vessel.

space for additional equipment to be fitted during the vessel's life.

For all these functions, the design philosophy in this manual is appropriate. All the necessary spaces can be defined as functional spaces and included in the spatial analysis of the vessel.

Where withdrawal or access spaces are defined at an early stage of design, then service routes can be located so as to avoid interference. At the same time it is possible to create additional envelopes which will contain new equipment to be fitted to the ship at a later date. Such envelopes would be sized to meet all known requirements. The envelope then forms a major input into the specification and design of future equipment.

Repair requirements are inherently less predictable than maintenance or overhaul, but involve the same need for access.

In a repair context, it is more likely that an individual item of equipment will require to be removed, rather than a complete assembly. The problem at the design stage is in the detail design of the functional spaces. It is therefore precisely the same problem as that faced by a designer in any conventional design system.

In the case of a massive machinery failure requiring major equipment removal, it would probably be necessary to remove and install the replacement compartment sideways through the shell.

#### 2.1.3.5 Conclusion

The structured approach to design, based on the spatial analysis and development of a vessel as a hierarchy of functional space , allows a variety of potentially conflicting requirements to be met.

**It** is arguable that the conventional design process does not necessarily take into account the operating requirements of maintenance, overhaul and repair.

The design which has been developed to enhance producibility can also enhance operating characteristics.

#### **2.1.4**     THE NEED FOR FORMALIZATION OF DESIGN PROCESSES AND-DOCUMENTATION

This manual places considerable emphasis on the need for the shipbuilder to have a consistent and well documented production system. He is then in a position to specify precisely the technical information he requires from design, and its timing. In order for the design system to respond, it requires a formal set of processes. Five design stages are defined, each with a specific set of inputs (including production) and outputs. Design documentation has to satisfy various differing requirements and therefore needs to be tailored to meet these with precision.

#### CROSS-REFERENCES

- 1.2.4     Shipbuilding Policy Framework
- 2.1.5     Need for Standard Terms of Reference for Design Agents
- 2.2       Ship Design Stages
- 2.2.7     The Format of Engineering Information

### 2.1.4.1 Introduction

The main theme of this manual is that the design process is a major factor in the determination of the work content, producibility and ultimate cost of a vessel. Given the overall objective of the industry, which is to reduce the cost of vessels, design/production integration is one of the three factors to be addressed. The others are facilities and organization. The three cannot sensibly be isolated, in that each impacts the others. One of the prerequisites for a producible design is that the production facilities and processes must be clearly defined. In addition, production rates that meet the financial objectives of the builder, material control and other operating systems must also be explicit. There is considerable emphasis on the need to formalize, via documentation, the methods to be applied to production.

This documentation forms a very sound basis for informing the designer about production requirements, to be met as far as possible compatible with the vessel functional requirements.

The builder should also have, within an overall shipbuilding policy, a type plan for his usual product range. This allows, at a very early stage of discussions on a possible contract, overall schedules to be prepared which identify **due dates** for the various production phases, and for the preparation of design and technical information. It is therefore possible for a builder, or potential builder, to specify fairly precisely his needs in terms of information.

The question which is addressed in this chapter is, "How should the design function respond to this?"

#### **2.1.4.2 The Need for Formalization**

The answer to the question is that the design function should respond by itself adopting a more formal approach.

Why is this necessary?

There is pressure to produce vessels to tight schedules. Despite all efforts by builders to reduce the construction time, there is still typically only a short lead time for design before production must start. In order to respond, design must meet the schedule requirements of production. A structured design process is essential to this, so that precisely the correct information, and only the correct information, is produced at the scheduled time.

Foreign competitors who are productive have achieved this close scheduling relationship between the design and production functions. They also deal with the lead time problem, and achieve cost reductions, by extensive use of previous ship data. These data are not simply filed for possible, haphazard future reference. Rather, the results of production are assessed and the previous design data are developed as a set of standards, based on both ship design and production needs. In appropriate cases, industry-wide standards are developed. These can range from simple structural details to complete outfit assemblies. The use of these standards fits into a highly structured design process.

Many key design features must be determined at an early stage, often before contract. In order to avoid a costly impact on production, some assessment must be made of how these features are to be made. Clearly this cannot be successfully accomplished without a formal process.



If the design **process** is not formalized, there are a number of potentiall damaging results which can occur:

The design may progress on a basis which is efficient for the designer and minimizes his costs. **If** this is done independently of production requirements, information which is needed to begin production may not be available on time.

The information produced may be spared to the functional requirements of the vessel. Important elements for the production **side** may be missing, which will again cause delays.

In the early stages, information recmired for cost estimating purposes may not be produced when needed, or may not be in sufficient detail.

**If no** account is taken of the facilities and process to be **used**, additional costs may be incurred because the builder cannot function at the level of efficiency he expected.

Material or equipment may not be specified in time to meet procurement lead time, with consequent late delivery to the builder.

### **2.1.4.3 A Structured Approach to Design**

The approach outlined in this section is amplified in Volume 2, Part 2. Its basis is to break the design process into a number of stages, which reflect the realities of the overall ship design and production scheme.

For each stage a set of inputs can be defined, which are necessary before the beginning of that stage. These inputs include external data from the prospective owner and others who specify vessel **mission requirements**, **outputs from the previous** design stages and production inputs.

There are five stages:

- Conceptual Design
- Contract Design
- Functional Design
- Transition Design
- Detail Design

Each of these is considered separately in its own chapter of Volume 2, Part 2, and are outlined in this section. Each stage increases the level of detail of a design, from initial concept to detail manufacturing instructions.

Conceptual Design

To **establish over-all features of a design to meet** owner requirements:

## Inputs

Service requirements  
Routes  
Market forecasts  
Technical change

**outputs**

Preliminary **general arrangement, midship** section  
Preliminary specification  
Preliminary calculations (dimensions, capacities, etc)  
Preliminary **body** plan

If at this stage a shipbuilder has been identified the following production inputs and outputs are essential:

Production Inputs - Shipbuilding policy:  
type plan  
facility dimensions

Production Outputs - Preliminary block breakdown  
- Zone. identification

Contract Design

To establish the features of a design sufficient to provide the basis of a contractual arrangement:

Inputs	Conceptual design Functional requirements Regulations Design standards
Production Inputs -	Shipbuilding policy Company standards and industry standards, including: material sizes modules service runs block sizes spatial analysis
<b>outputs</b>	General arrangement, midship section Specification Body plan Ship calculations Propulsion calculations Accommodation arrangements Machinery arrangements Piping diagrams Electrical load analysis Plan list
Production Outputs -	Preliminary build strategy: planning units Equipment identification: long lead items Material requirements: quantities long lead items

### Functional Design

To establish features of a design for the purposes of classification and other approval and material specification:

- |                    |   |
|--------------------|---|
| Inputs             | <ul style="list-style-type: none"> <li>Preliminary design</li> <li>- Functional requirements</li> </ul>   |
| Production Inputs  | <ul style="list-style-type: none"> <li>- Preliminary build strategy</li> <li>- Standards</li> <li>- Production processes</li> <li>- Facilities</li> </ul>   |
| outputs            | <ul style="list-style-type: none"> <li>- Ship design:               <ul style="list-style-type: none"> <li>hull form</li> <li>trim and stability</li> <li>capacities, etc</li> </ul> </li> <li>Structural design:               <ul style="list-style-type: none"> <li>approval drawings, scantling plans</li> </ul> </li> <li>Machinery installation:               <ul style="list-style-type: none"> <li>arrangement</li> <li>pip ing diagrams</li> <li>electrical</li> <li>fittings, etc</li> </ul> </li> <li>- Accommodation design</li> <li>Ship systems design</li> <li>- Hull outfit</li> </ul> |
| Production Outputs | <ul style="list-style-type: none"> <li>- Contract build strategy</li> <li>- Schedules:               <ul style="list-style-type: none"> <li>erection/installation</li> <li>assembly</li> <li>manufacture</li> </ul> </li> <li>- Production information</li> <li>Purchasing information</li> </ul>   |

### Transition Design

To translate the features of the design from the system orientation, necessary to establish functional performance, to a planning unit orientation, necessary to establish production requirements.

Transition design develops elements of systems into steel and outfit zone composites. It should be based on the spatial analysis of earlier design stages.

However, for effective design for production to take place, production needs and capacities should be highlighted from the earliest stage:

Inputs	Conceptual design Contract design Functional design
outputs	Process analysis Interim products Work package information Workstation drawing information

### Detail Design

To establish the features of the design necessary to allow local purchasing, part manufacturing and subsequent assembly to be carried out.

Detail design is carried out by planning unit, on those elements of the ship which have been developed to the stage where all functional and approval requirements have been satisfied.

#### Inputs

- Functional design
- Transition design
- Build strategy
- Standards
- Work station capacities
- Process analysis

#### outputs

- Work instructions
- Work station drawings
- Material lists
- Dimensional requirements

#### 2.1.4.4 Design Documentation

It is important to have and to maintain a clear picture of the function of all design information-. Design, in this case, is used to cover the complete range of activities, from concept to final detail, which is necessary to defining a vessel. Design information will therefore have a number of functions.

**In general these can be reduced to two main groups:**

Information related to the function of the vessel ,  
including:

- hull form
- structural arrangement
- powering

and other information which is external to the production function such as flow rates and capacities.

Information related to the production of the vessel ,  
including:

- parts lists
- manufacturing definition
- assembly instructions

and other information internal to the production function such as jig arrangements and fairing aids.

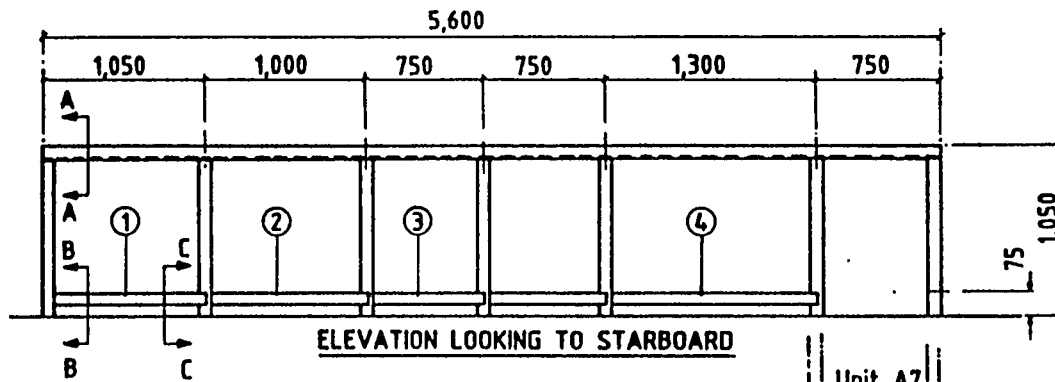
The information which is produced should be specific to the requirements of the user. It should have adequate detail for the user, but should not obscure the detail which is necessary with that which is superfluous.



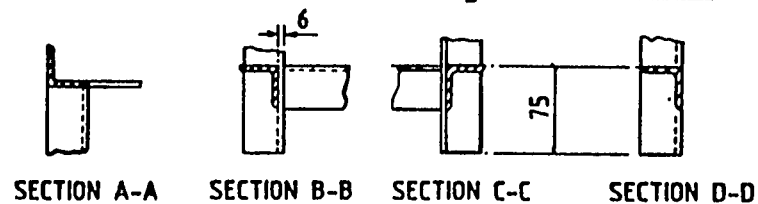
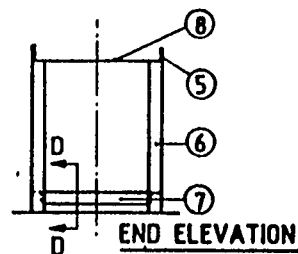
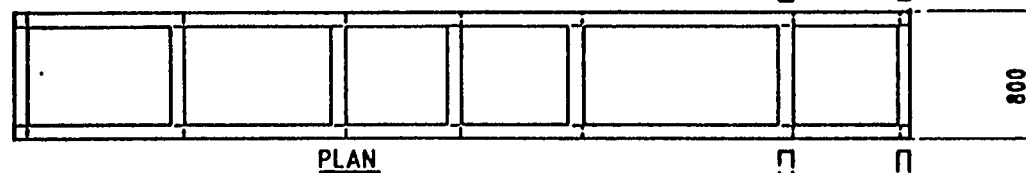
Perhaps the clearest example of tailoring information to specific user requirements is the work station drawing. The work station drawing is the final output of the design process, and shows all the characteristics of formalized documentation.

Although an initial reaction may well be that this approach involves considerably more work, this is not necessarily the case. Particularly as more use is made of CAD/CAM (CAE) **(CIM)**, the process of design becomes increasingly one of creating a single data base. This is developed in increasing detail as the design progresses, the sequence and pace of development being dictated by the needs of material procurement and production, as well as defining functional aspects.

Information is then selectively extracted from this database, in the most appropriate form for the user.



Part No.	Qty	Material	Dimensions
1	2	60x60x8 rsa	997 long
2	2		1,000 long
3	4		750 long
4	2		1,300 long
5	2		5,600 long
6	14		990 long
7	7		680 long
8	7	60x10 flat	680 long



## OUTFIT STEEL ASSEMBLY FOR PIPE MODULE

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#### 2.1.5 NEED FOR STANDARD TERMS OF REFERENCE FOR DESIGN AGENIS

For a cost effective vessel to be designed and built, both the designer and builder must have well-structured and formalized organizations. This situation allows the transfer of information to be both precise and timely. However, it does not ensure that this orderly transfer of information will be achieved.

To do so it is necessary to specify the complete set of information which is required from the designer and other parties as standard terms of reference. A subset of these can then be extracted for a particular contractual arrangement.

#### CROSS-REFERENCES

2.1.4 Need for Formalization of Design Processes and Documentation

2.2 Ship Design Stages

#### 2.1.5.1 Background

This manual emphasizes, among other requirements, the need for a consistent approach to the various activities associated with the design and production of a ship. A standard approach, to construction, a well defined hierarchy of interim products and a structured design process are all essential to the overall goal of improved producibility.

In the previous chapter, a formalized approach to the design process was outlined. This approach is based on identifying the form and content of the information which is input to and output from a series of stages which take the design from concept to detail. It is desirable that this structured approach should be adopted in all cases, and should be the basis for the terms of reference for a design agent.

The shipbuilder can determine, through his shipbuilding policy, the way in which he will build a given ship type. The processes are predetermined, as is the level of advanced outfitting and zone installation. In short, the production system is in place. For each contract only timescales need to be added. Management can then concentrate on the small number of unusual features which inevitably occur.

Following a clear shipbuilding policy allows the builder to develop precise information requirements from the design function, in terms of form, content and timing. The results of achieving or not achieving these requirements can be determined.

### 2.1.5.2 Potential Problems

For the orderly process described above to exist, the builder must initiate and the designer must respond. Failure to do so can generate a series of problems. Some are clear and well understood. Others are obscured by being part of an existing "normal" situation, and are only identifiable by reference to the activities and performance of more productive competitors.

If the terms of reference and the specific information to be provided are not clear, consequences can be:

Required information is not available to production and either a delay will occur or re-work will be necessary later.

Information is not provided and additional cost is incurred in developing it.

Revisions to the design are introduced at a late stage, causing delay and introducing additional cost.

Different interpretations of the design information are made, causing delay during their resolution.

**All** of these, and other consequences, will result in a cost increase and delay. The allocation of cost and responsibility between the design and production functions is a further cause of problems.

The terms of reference may fail to specify the timing of information. This can result in:

Late delivery of information to production, with consequent schedule problems.

Late delivery of equipment from vendors.

Late delivery by subcontractors.

Late revisions to elements of the design, where no date for finalization has been agreed.

Areas of the design which present difficulties may be "shelved" in favor of routine aspects, despite their critical importance to the production schedule.

Whereas none of these problems will necessarily be totally avoided by clear terms of reference, a large degree of uncertainty can be removed.

#### 2.1.5.3 Terms of Reference

The design and development of a vessel is too large and complex a project to be controlled other than by a comprehensive and detailed planning system. The system can be responsive and largely decentralized, but must be effective. It must include the supply of design information which is a major input to production.

The terms of reference for the design agent would include, among other elements, a detailed specification of the information to be produced by the designer, and its timing, together with the required production inputs. The basis could be the five design stages outlined in the previous chapter and the input and output requirements of each.

The five stages are:

- conceptual design,
- contract design,
- functional design,
- transition design,
- detail design.

Any individual ship design or contract situation would be unique in terms of the allocation of responsibilities between the prospective vessel owner, the design agent, subcontractors, vendors and builder. The terms of reference would have two functions:

To specify all the information necessary for ship production. This would assume the full application of design for production, with provision for use of any available standards. The builder would be assumed to have a shipbuilding policy.

From the complete set, the appropriate sub-set would be used for the particular situation, whether a hull design and build project, or a limited design study.

For each element, responsibility would be allocated for the provision of necessary inputs to that element, and for production of the output of that element.

To agree to the timing of the production of all the necessary information. This would be based on the appropriate levels of planning, and would be designed to ensure that the production and lead times were fully considered in determining the overall contract duration and necessary due dates.

The formality of such terms of reference would be greater where there are several design agents associated with a shipbuilding project. Nevertheless, the detailed specification and timing of design information is a crucial element in the performance of successful shipbuilders.



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#### 2.1.6 IMPACT OF FACILITIES ON DESIGN

This manual asks the ship designer to view a vessel not only as a complete entity, with a mission to perform, but also as a collection of assemblies which must be made and joined to produce the finished vessel. These assemblies should be designed so that the best utilization of the production facilities is achieved. The designer is therefore asked to consider such aspects as maximum plate size and panel size in relation to hold length. With respect to outfit installation, the capacity of the shipyard to produce outfit assemblies should be considered in the design.

#### CROSS-REFERENCES

2.1.7 The Need to Document Facility Capability

2.3 Ship Production

### 2.1.6.1 Introduction

A ship is conventionally designed to perform a function or functions. The designer is therefore concerned with the ship as a whole, for aspects such as hydrodynamic performance and for carrying capacity. He is concerned with the systems on the ship as whole systems. This applies to cargo pumping systems on a tanker, machinery systems or weapons systems. This manual seeks to add another dimension - the requirements of production - to the design process.

This requires the designer to consider a vessel not only as a complete entity, composed of various systems, but also as a collection and assembly of individual elements.

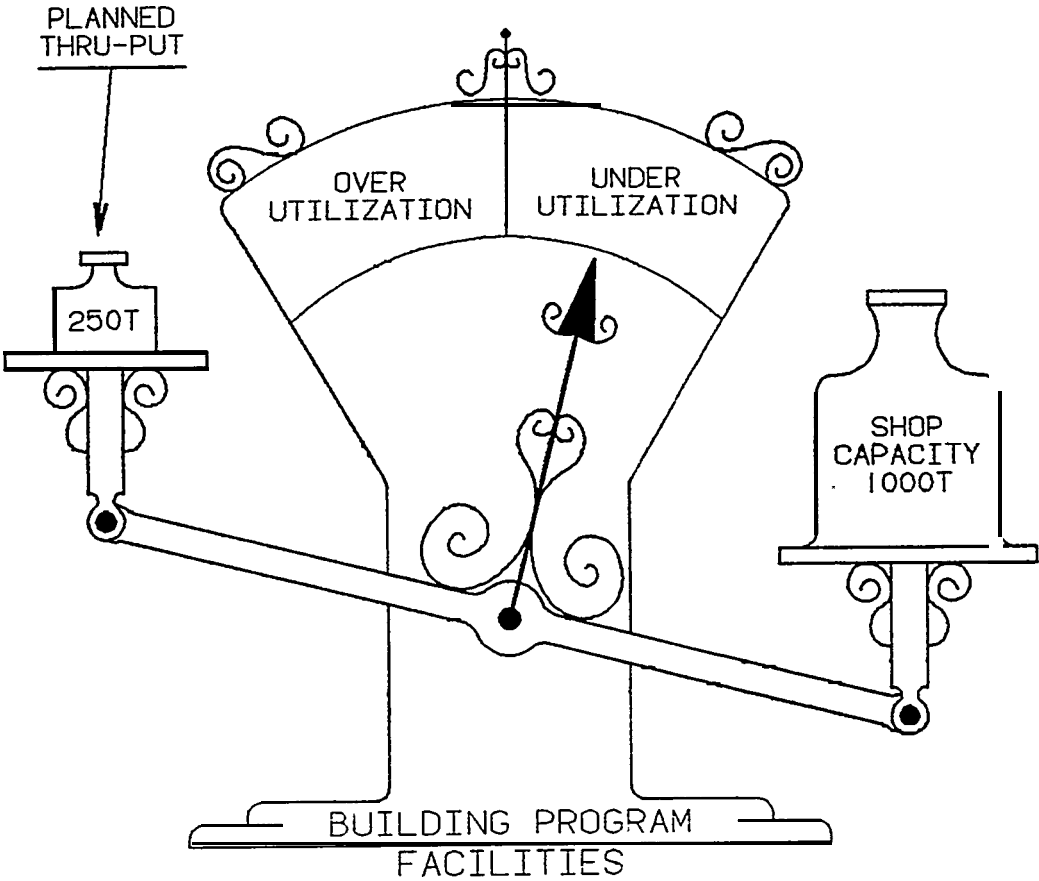
The characteristics of these elements will be determined to a considerable extent by the facilities available for their production. This chapter outlines the way in which facilities can impact desire. The impact is not apparent unless it is made explicit, ideally through the documentation of the various facilities which are available, and the presentation of selected information to designers at the appropriate stage in the design process. Guidelines for this are given in part 3 of this volume.

Even if the facilities question is ignored by the designer, the impact may not be apparent, especially to him. The impact will exist, nonetheless, in ways which can be seen on the shop floor. For example:

under-used assembly area because the plate length imposed by design is shorter than the maximum.

additional panel butt welding because the maximum plate width has been ignored.

additional ship-board installation because the outfit assembly capability has not been considered.



#### 2.1.6.2 Construction Facilities

Within any shipyard, available facilities impose major constraints when determining the size of ship to be constructed.

The first of these constraints is the construction area, which may be either a traditional slipway or dock. In either case, the maximum width of the ship will be governed by the width of the slipway between crane tracks or by the width of the dock entrance. The length of the construction area is important, but not quite so critical in that it is possible to build ships in two halves which can be joined together afloat after launch or float out. Little can be done if the ship is too wide for existing facilities.

The number of cranes and their capacity, either individually or collectively, available in the ship construction area will be significant when defining the steel units which will be erected to the slipway or dock. The problem will be even more acute if cranes are available on only one side of the slipway or dock, in that the maximum lifting for the steel units will be greater on the side of the ship nearest to the crane than those steel units on the opposite side of the ship.

A lack of adequate crane capacity at the construction stage will severely restrict the sizes of steel unit and the extensive use of advanced outfitting techniques.

SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV
			DATE

RAW MATERIAL SIZES - PLATES

PLATE LENGTH

STANDARD PLATE LENGTH = 25 ft

PLATE BREADTH

STANDARD PLATE BREADTH = 8ft 6

PREFERRED PLATE BREADTH = ft

ft

PLATE THICKNESS

STANDARD THICKNESSES =

ins

ins

ins

ins

ins

QUALITY

QUALITY	MAXMUM LENGTH	MAXIMUM BREADTH	THICKNESSES
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### 2.1.6.3 Steel Production Facilities

There are a number of other important constraints which have to be considered. They include:

- assembly shop capability,
- steel treatment and preparation capability,
- outfit assembly capability,
- road access between assembly and erection areas.

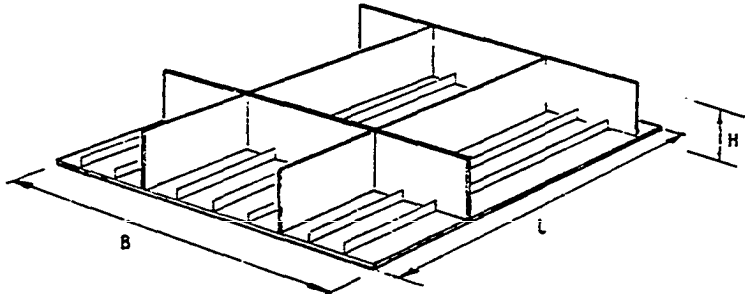
Assembly shop capability is determined by the maximum lifting weight of cranes, both individually and working in tandem. The lifting height of the cranes restricts the ability to turn over large units. The size of exit doors will constrain the width and height of the steel units. Methods of transportation Used to transfer the steel unit from the steel assembly shop to the construction area may also impose weight and dimensional restrictions.

Steel treatment and preparation capability relates to the maximum size of plates which can be processed through the shotblast, painting, cutting and forming processes.

Shotblasting and painting equipment will not normally impose any major problems on plate sizes, although the maximum width of plate to be handled will be determined by the width of the shotblast machine.

The maximum size plate capable of being cut by machine may be constrained by length, width, or a combination of both, depending on the specification and configuration of the cutting machine and cutting table.

The forming of shaped plates will be governed by the size, capacity and location of the forming machines.

SHIPYARD NAME	CHAP	SECTION	SHEET No									
FACILITY CAPABILITY DOCUMENTATION		REV	DATE									
<b>MAXIMUM ASSEMBLY SIZE AND WEIGHT</b>												
<div style="display: flex; justify-content: space-between; align-items: flex-start;"> <div style="width: 60%;"> <p>NAME : Flat Panel Assembly</p> </div> <div style="width: 35%; border: 1px solid black; padding: 5px; text-align: center;"> CODE   FP </div> </div> <div style="text-align: center; margin-top: 20px;">  </div>												
<p><b>MAXIMUM SIZE</b></p> <table style="margin-left: auto; margin-right: auto;"> <tr> <td style="padding: 0 20px;">L</td> <td style="padding: 0 20px;">-</td> <td>28 ft</td> </tr> <tr> <td style="padding: 0 20px;">B</td> <td style="padding: 0 20px;">-</td> <td>15 ft 3</td> </tr> <tr> <td style="padding: 0 20px;">H</td> <td style="padding: 0 20px;">-</td> <td>7 ft 6</td> </tr> </table> <p style="margin-top: 20px;"><b>COMMENTS :</b>   L limited by shop door width                                H limited by available standard plate width</p>				L	-	28 ft	B	-	15 ft 3	H	-	7 ft 6
L	-	28 ft										
B	-	15 ft 3										
H	-	7 ft 6										
<p><b>MAXIMUM WEIGHT</b></p> <p style="margin-left: 40px;">Straight Lift   =   19.5 t</p> <p style="margin-left: 40px;">Turnover Lift   =   9.5 t</p> <p style="margin-top: 20px;"><b>COMMENTS :</b>   Shop Craneage   =   2 x 10 t</p>												



Shell rolls and flanging machines will constrain the length and thickness of plates. Because of such a constraint, it is very often the case that the maximum length of formed plates is shorter than that of flat plates. Such an imbalance is usually a result of incorrectly specifying forming machines or a lack of awareness of preceding and succeeding process operations.

The physical location of forming machines close to walls, walkways, entrances, exits and other machine tools may also affect the length and/or width of plate to be handled, even though the machine itself is capable of handling the maximum size of plates to be specified.

#### 2.1.6.4 Outfit Assembly Facilities

A. shipyard's desire to develop and construct integrated assemblies of outfit equipment and manufactured outfit parts on to a steel foundation will require a suitable building to construct such assemblies. Obviously the crane capacity, door sizes and transport system will influence the configuration and size of outfit assemblies to be designed and manufactured.

Road access for transportation of steel and outfit assemblies between assembly and construction areas will also influence the weight and dimensions of the various assemblies. Ideally, all roads together with a suitable transport system will have been designed to take the maximum weight and size of the heaviest load likely to be lifted to the shipway or dock. Anything less will impose constraints to the ship design which can only add unwanted costs to the ship construction process.

## 2.1.7 THE NEED TO DOCUMENT FACILITY CAPABILITY AND CONSTRAINTS

It is central to this Manual that the designer must take account of production. This cannot be achieved without documentation, because of the volume of information involved. Without documentation, the transfer of data from production to design will be a lottery, or will rely on memory. Although a lot of documentation is needed, only a small part will be used at any time by an individual, and careful structuring will simplify the task of identifying that which is relevant.

### CROSS-REFERENCES

- 1.1.2 The Productivity Gap
- 1.2.4 Shipbuilding Policy Framework
- 2.1.4 Need for Formalization of Design Processes and Documentation
- 2.1.8 Need to Document Production Processes and Method Information
- 2.3 Ship Production

## 2.1.7 THE NEED TO DOCUMENT FACILITY CAPABILITY AND CONSTRAINTS

### 2.1.7.1 Background

The impact on the cost of producing a vessel which can result from ignoring the design/production interface is considerable. As far as is possible, consistent with ship performance, the designer should take production into account. Few designers would disagree with this. Many have experience of production which they incorporate into their work.

On the other hand, there are many individuals in design offices who do not have sufficient, or indeed any, production experience. Such experience as they have may well have been unstructured, or may simply have been acquired a long time ago.

**No formal study has been undertaken as to the way in which facilities are not adequately considered by the designer. Nevertheless, there are numerous anecdotes which describe this subject. The differences in design features, in utilization of facilities and finally in competitive performance between shipbuilding countries and companies underscores the need for designer to understand the facilities used to produce a product from his design effort.**

### 2.1.7.2 Why Document?

The thought, or threat, of more documents - more paper - is a powerful factor concerning the production facilities documentation. Why, therefore, is it necessary to document facilities data?

The answer to that question is two-fold. Firstly, the complexity and variety of facilities, especially where several shipyards must be considered, makes it impossible for any designer or group of designers to remember all the relevant information. Secondly, the type and detail of information which is necessary at different stages of design varies, and a structured format can simplify the identification of the relevant material. Although a large quantity of information is involved only a relatively small amount is required at any stage.

### 2.1.7.3 Information Requirements

In order to produce a production "friendly" design the designer must have a thorough appreciation of the capabilities and limitations of the facilities to be used in the making of the product. The designer must also understand the materials to be used and the problems associated with their transportation and handling.

The designer's first consideration must be "raw" material and purchased equipment. It is necessary to know the manufacturer's capabilities regarding quality, specification, standards, manufacturing tolerances and the means of transportation of these items to the point of use.

It is then necessary to know of internal constraints such as access ways, storage facilities, lifting facilities, manufacturing and assembly facilities, for example machines or areas in terms of size, weight, weldability, installation, etc.

A well maintained technical library will provide information on materials, equipment and the various national and international standards. Details of the capabilities and capacities of internal production facilities may be contained within a facilities manual. This would contain detailed information regarding plant layout including details of every work site. In the stockyard and material treatment areas details would be available of storage area, crane capacities and types and the capabilities of each piece of production equipment. In the manufacturing areas details would be available of each machine tool and work site, door sizes, crane capacities and types, materials handling and storage facilities, manufacturing tolerances and types of materials and material sizes that can be processed.

In the various assembly areas, details of access ways and door openings, crane capacities and turning methods including lifting beams would be available. Details would also be available concerning welding and cutting services along with those of compressed air and electrical power outlets. Details would also be available of erection and finishing areas providing information regarding the size of vessels that may be accommodated, ground loading data, crane types, lifting and turning capabilities, production services availability" water depths, etc.

**Details of lifting capacities of cranes, lifting beams and transportation equipment would also be contained within the facilities manual. In the event of large structures being brought to the shipyard by sea or road, details would be available of access ways, heights of cables and off-loading facilities.**

In the event of CAD/CAM systems being installed all the above data would be stored within the data files for ready access by the designer. Detailed knowledge of a facility's capabilities and constraints will help to ensure that products are designed that may be economically and readily produced by that facility and, when properly maintained and updated, will not only service the experienced designer but will also help with the speedy induction of new technical staff.

#### 2. 1.8     THE NEED TO DOCUMENT PRODUCTION PROCESS AND METHOD INFORMATION

Facilities will impact the earlier design stages. As work on a contract progresses, the detail design should take into account the production processes and methods in use. In order to take these factors into account, it is essential to document them. Not only is the volume of information beyond the memory of individuals, but a policy of improvement in shipbuilding will necessitate frequent updating. There is a danger of memorized or "well known" information being out of date.

#### CROSS-REFERENCES

- 2.1.7     The Need to Document Facility Capability and Constraints
- 2.3       Ship Production

#### 2.1.8.1 Introduction

The need to document information regarding production processes and methods is similar to that of documenting information about the facility itself. Due to the fact that processes and methods change more frequently than much of the facility, the need is probably greater.

In order for the design of the ship to be suited to efficient production in a particular shipyard, the designer must be aware not only of the shipyard facilities but also of the standard or preferred processes and methods used by production. This information must be documented and available to the designer in increasing detail according to design stage.

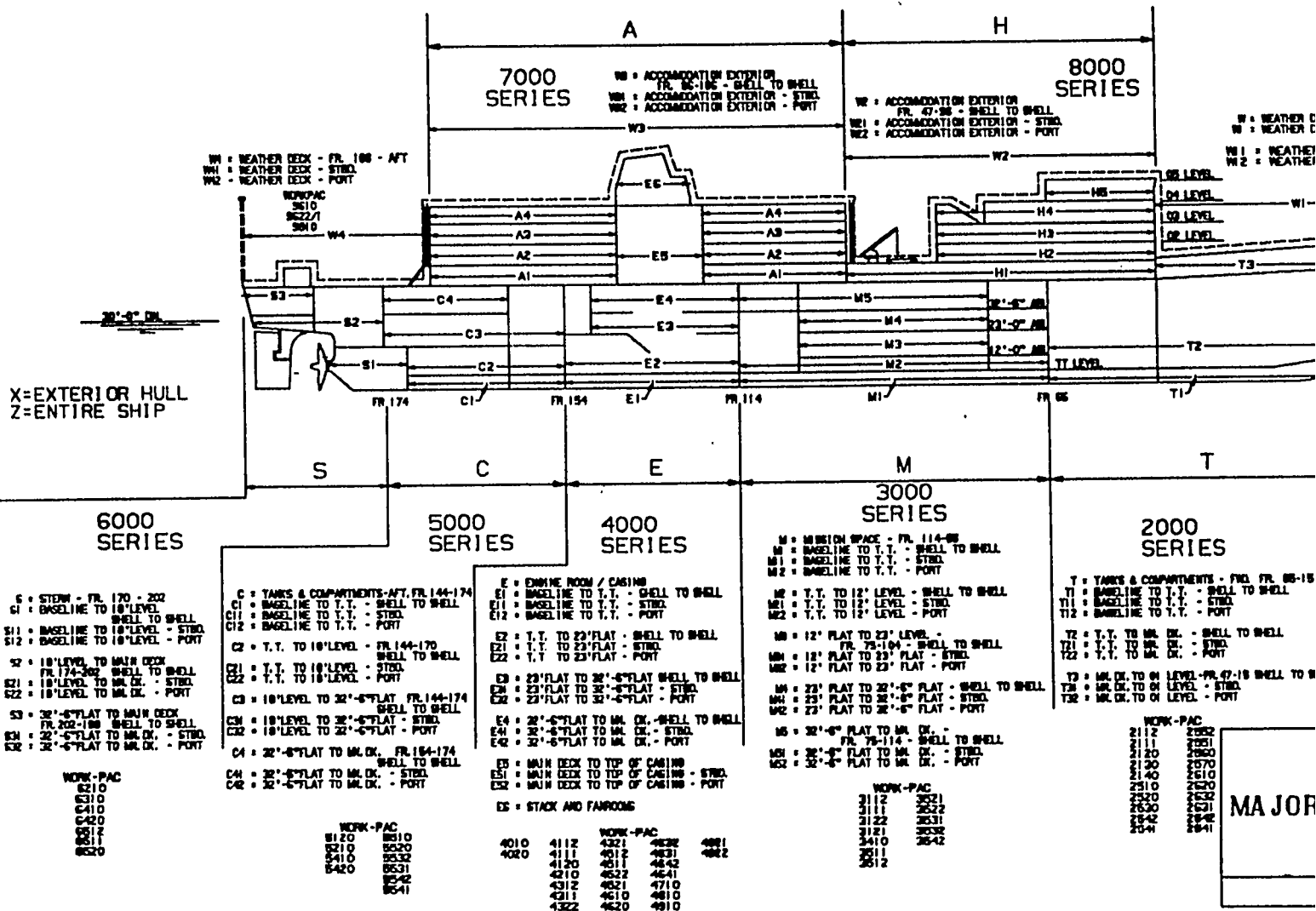
At the earliest design stage the need is for a block breakdown, showing the preferred erection method. This is then extended to information on how each block is assembled. At the detail design level detailed information is required, such as welding processes and their related edge preparation requirements and accuracy control methods.

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A1 = MR. DE. TO 04 LEVEL - SHELL TO SHELL  
A11 = MR. DE. TO 04 LEVEL - STBD.  
A12 = MR. DE. TO 04 LEVEL - PORT  
A2 = 04 LEVEL TO 05 LEVEL - SHELL TO SHELL  
A21 = 04 LEVEL TO 05 LEVEL - STBD.  
A22 = 04 LEVEL TO 05 LEVEL - PORT  
A3 = 05 LEVEL TO 06 LEVEL - SHELL TO SHELL  
A31 = 05 LEVEL TO 06 LEVEL - STBD.  
A32 = 05 LEVEL TO 06 LEVEL - PORT  
A4 = 06 LEVEL TO 04 LEVEL - SHELL TO SHELL  
A41 = 06 LEVEL TO 04 LEVEL - STBD.  
A42 = 06 LEVEL TO 04 LEVEL - PORT

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#### 2. 1. 8. 2 Documentation

As with the question of facilities documentation, the need to set all the information out on paper (or through an electronic medium, accessed by a screen) must be established. The objections, in terms of the volume of data which is involved, can be countered by the same arguments which apply in the case of facilities. The total quantity of data defines the need. In order for the designer to properly take into account production requirements, he must have access to a description of which production processes are used. For any specific design case, especially at the detail level, the designer only needs one or two pieces of information. These might be the configuration of a particular interim product and a preferred structural connection, or a preferred outfit installation method.

The designer is not expected to read or study all the process documentation. The volume of information is irrelevant to the individual with a particular task. Without documentation, the designer has little chance of discovering what production requirements are.

In order to meet the designer's needs, any documentation must be well structured and categorized. In that way it will be simple for the information for a particular user to be found quickly. The organization of the information should be based on the design stages, since the level of detail and type of information needed varies from stage to stage.

A knowledge of the facility is particularly useful at the preliminary design stage, prior to the contract being signed. A wide knowledge of production processes and methods is most important during the subsequent design stages. It is this understanding of production that facilitates the preparation of production friendly designs.



It is particularly important to know the process flows and which interim products are processed through each. When preparing a design it is important to strive toward reducing variety thus enabling more interim products to be processed through fewer process flows thereby enabling the principles of mass production to be applied. Thus there should be a file of data listing all the various interim product types. For each type there should be details of the manufacturing and assembly processes and sequences required for their manufacture. Finished tolerances and, where appropriate, material excesses and allowances should also be detailed.

Where more than one trade is involved with the making of an interim product it is important to understand the inter-relationships between the different trade activities in order to design each interim product of that type such that it is as nearly identical as possible to all others of the same type in terms of work content or work mix. This facilitates the achievement of high labor utilization and hence high productivity,

Where CAD/CAM is used all the above information may be stored in the data base for ready access and is easily updated.

### 2.1.9 COMMUNICATION BETWEEN DESIGN AND PRODUCTION

Communication, as a two-way process, is essential to the design and production of cost effective vessels. It is essential to have clear terms of reference and to document all the necessary design and production data.

But this is not sufficient to ensure understanding. The training and experience of the people involved must include time spent in disciplines other than their own specialization. In particular, designers need practical shipbuilding experience.

Planning also has a major communication role in ensuring that the timing of information transfer is correct.

### CROSS-REFERENCES

- 1.2.4 Shipbuilding Policy Framework
- 2.1.5 Need for Standard Terms of Reference for Design Agents
- 2.2.7 Format of Engineering Information

#### 2.1.9.1 Introduction

The two previous chapters have described the need for and importance of up-to-date documentation describing the facilities available in a shipbuilding company and the production processes in use. This documentation is an important element in the process of communication between design and production.

Communication must be a two way process. The designer communicates with production, not simply by providing information in a traditional form. Rather, the information provided must reflect the particular requirements of the production facilities to be used. To achieve this goal, and the benefits associated with that achievement, is the primary aim of this whole manual.

A further area where good communications are essential is that relating to design errors or essential changes. In the case of the former it is particularly important to establish a highly efficient feedback system to ensure that the offending drawings are modified as quickly as possible with a view to ensuring that they do not affect other areas of the same project or the same areas of follow-on projects. In the case of the latter it is most important to identify the impact of design changes on the production program and to decide on the most appropriate time to implement the change.

The designer can only provide this form of information if the producer has already provided the necessary reference material. In addition, feedback on actual operations must be provided, and both producer and designer must be prepared to act on the feedback to provide greater design/production integration in the future.

### 2.1.9.2 Training and Experience

It is not possible to prepare "standards" and document them in such a way that a designer with no production knowledge can prepare a design with inherent producibility. Both the vessel technology and the methods of production are dynamic. There are also unforeseen changes, problems requiring compromises and other areas where interpretation of the production or design standard is needed. For this interpretation to reflect the requirements of design/production integration, it is essential that the designer who must make the interpretation has an understanding of the production process.

It is important to know not only WHAT production needs but also WHY. It is also the case that many designers have no shipbuilding experience which will allow them to develop an understanding. Even in cases where the design and production functions are part of the same company, it is not uncommon for the communication between them to be poor. However, *in* these cases the problems may be more organizational, or based on conflicting objectives, rather than due to total inexperience. It is possible to find designers who have not seen the production facilities of the shipyard in which they operate.

One method of resolving the communication problem is *to* ensure that all new design staff spend a period before, during or immediately after their formal design training working in a shipyard production area,

Even assuming that during the period of initial training, design personnel are well trained with regard to their knowledge and experience of production processes and methods, as time progresses and processes and methods change there will be a need to update the designer's previous experience.

The importance of the designer's early training cannot be overstressed. It is during this formative period that the interest in production activities must be developed and the essential experience in the working of the materials used in shipbuilding, and of work processes and methods used, is gained. Just as it is important to understand the technical capabilities of musicians and their instruments to write good music, so it is also important to understand materials and the methods and processes used to work with them in order to be a successful designer.

Thus it is the designer's early training that establishes foundations for a communications bridge between the designer and production function. The nature of the bridge will naturally depend on the stage of design. At the contract design stage, for example, the link would be through regular involvement with production management and senior production engineers developing the company's shipbuilding strategy and manufacturing standards or when preparing a build strategy document for a product.

At the functional and transition design stages the designer needs to be in touch with the quality and process engineers, staff engineers and production department managers. At the detail design stage the designer must maintain an ongoing relationship with production planners, foremen and operatives, detail planning, accuracy control and staff engineers.

The role that a designer could adopt is that of production engineer with the responsibility of taking problems which have been identified by production and trying to develop more productive solutions. The solutions would then be discussed with both design and production.

The actual mechanism for the communication and feedback processes discussed in Part 3 of this volume.

For further experience, roles could be developed for design staff liaison between design and production. For this they would be based in a shipyard, again to gain exposure to production problems.

Another possible option is for staff from a design agent to spend a period in a shipyard early in their design career. They would take on a production role and for the duration of the period, be treated as a member of shipyard staff. Similarly, shipyard staff could spend time with design agent. In this way both design and production would have people with a first-hand knowledge and understanding of the other's business.

The training process would require to be structured with a set of learning objectives and a reporting system which tests the training results.

#### 2.1.9.3 Formal Communication

The volume of necessary communication between the design and production functions is such that a formal set of procedures is essential. The basis of such communication is the input and output associated with the main stages of design. Responsibility for the preparation of each element of the total set of information will be defined by the terms of reference for the contract.

Determining the information requirements is a function of production engineering. Production engineering will act as a link between the design function, the production function and planning.

The formal communication will include a definition of the information to be supplied, the timing of that information and the various sets of standards and regulations which will apply. Not only the form of communication (drawing, sketch, schedule, computer tape), but also the content should be specified, by example.



#### 2.1.9.4 The Role of Planning

Following the definition of what production work is to be carried out, and how it is to be done, the planning function has the main task of determining when work is to be carried out. Planning must relate not only to the activities of the production departments, but also to the provision of information from design, and other technical areas. In this respect, the planning function acts as an important communication link between design and production.

Planning follows production engineering. For example, in the outfitting of a ship, the sequence would be:

The unit breakdown of the ship is established.

The erection sequence for the ship is established.

The unit breakdown is further developed into zones or working areas. A combination of the zones, the erection sequence and material deliveries is analyzed to give dates for pre-outfitting, open-sky outfitting and on-board outfitting.

The planning department will then work backwards from these dates to establish other key dates in the program. For example:

Latest date for fabrication of outfit assemblies.

Start date for fabrication of outfit assemblies.

Latest date for delivery of materials.

Date for ordering materials.

Date when technical information from suppliers is required.

Date when drawing should be completed.

Start date for drawings.

A more detailed level of planning is called for in which the planning office no longer demands the whole of a particular system to be completed by the design agent by a particular date but, instead, demands that all systems within a particular zone are completed and by which date it must be done.

#### 2.1.10 THE IMPLICATIONS OF SHORT LEAD TIME

Design lead time is the period between award of contract and start of production. It is the time available for developing the necessary production information. If the lead time is short it can result in late or incorrect information leading to cost and time overruns.

Whereas enforced short lead time causes serious problems, it is possible to take action so that planned short lead time can be a commercial advantage. **Use** of standards, careful planning of the information flow, parallel steel and outfit production, are among the means available to eliminate problems arising from short lead time.

#### CROSS-REFERENCES

#### 2.2 Ship Design Stages

#### 2. 1. 10. 1 Design Lead Time

In this context lead time is most simply defined as the period between contract award and the start of production. In some circumstances, the need to produce certain technical information, may require contract design work to begin prior to contract award. For example, there may be a long period between specification and the delivery of major items of equipment.

In a buoyant market, lead time is rarely perceived as a problem. Long order books and high demand result in lengthy periods between order placement and delivery. within the overall time there are considerable variations between individual shipbuilders in the use of the available time, and the proportion of the time allocated to pre-production and production activities. The efficiency of the technical and production departments will be the major determining factors.

In a depressed and highly competitive market, the lead time problems, which are hidden in good times, come sharply into focus. There are both internal and external factors which have an effect on lead time. External factors are those related to actions by the prospective shipowner. Internal factors are those related to production and design. The design may be a responsibility of the builder, or an independent design agent, or may be substantially carried out by the owner. However, the builder must take a lead, in his own and the other parties, interests, in mitigating the effects of short lead time. The external factors are largely unavoidable. The internal factors are avoidable and may be regarded as symptoms of wider problems.

Given the uncertainty of trading conditions and/or shortage of money, the owner naturally wishes to delay his expenditure for as long as possible. His tendency is to place orders later than the shipbuilder wishes. At the same time there is pressure on the shipbuilder to offer an early delivery date. The owner, having committed his money, wishes to see tangible results as early as possible.

Short project time imposed by external conditions leads to a number of potential problems for the builder. These may be compounded by "internal" inefficiencies. Design lead time will be determined by production time, and will be short if the latter is long. This may be so for a number of reasons, for example:

- Low Productivity
- Poor Accuracy Control
- Poor Planning

PII of which are within the control of the builder and which are his responsibility.

Sequential operations (the traditional approach to ship construction). At worst, the steel hull is completed and launched before outfitting commences.

In changing the method of operation, the design agent (from whatever source) must be involved, because the format, sequence and timing of the provision of technical information will change.

Inadequate facilities, and other physical reasons.

If the time available to develop technical information and prepare for production is short, there are a number of undesirable consequences.

Among the problems that can occur are:

- Late technical information, resulting in equipment deliveries behind schedule.

- Insufficient information, causing rework or delaying work to a later stage of production, with a cost over-run.

- Late production information, causing production to be late, or resulting in rework if changes must be made.

The overall result of these, and the most serious effect, is late delivery. Associated with this is cost over-run.

### 2.1.10.2 Reducing Effects of Short Lead Time

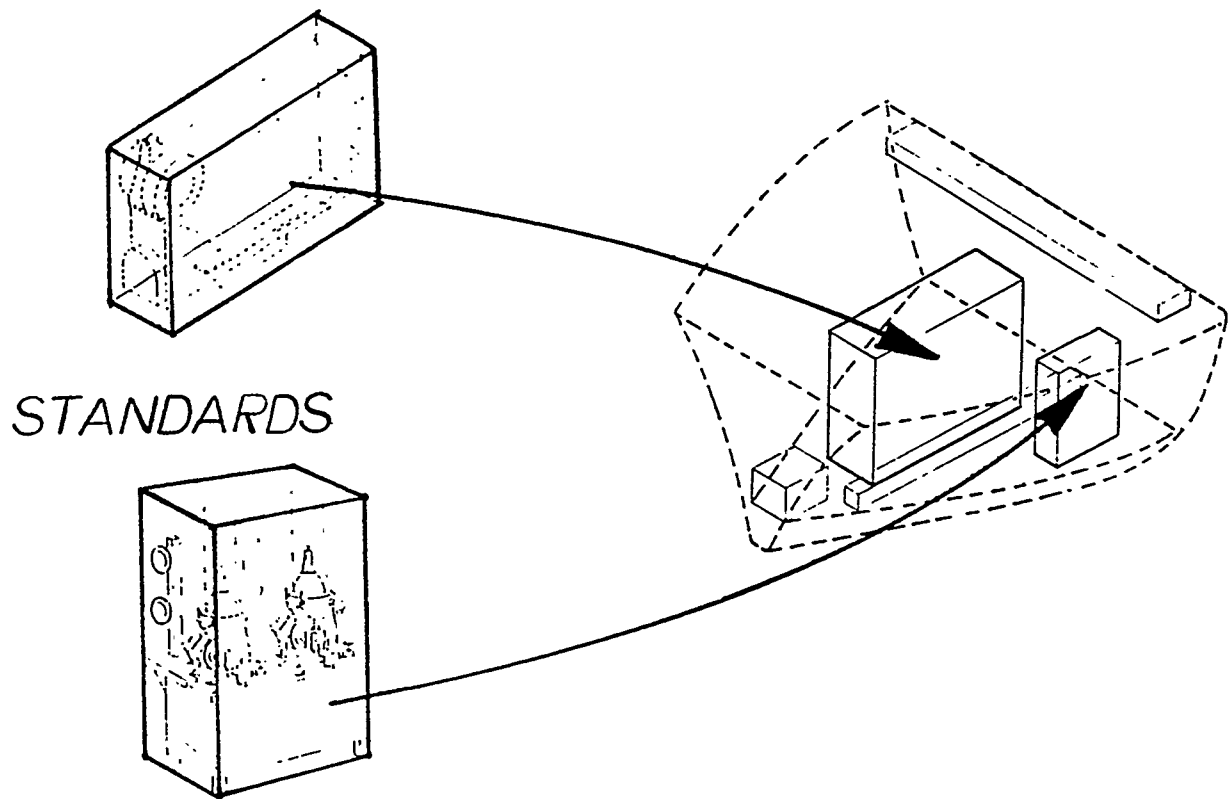
The shipbuilding policy developed by the company will recognize the reality of a competitive market and the short times available, and will actively seek to manage its operations so that short pre-production and production times are planned, to give a commercial advantage.

In order to shorten the project duration it is necessary to reduce the time between "authority to proceed" and "production start-up", while at the same time reducing the production cycle time, that is, the time from start of manufacture of parts to delivery of vessel.

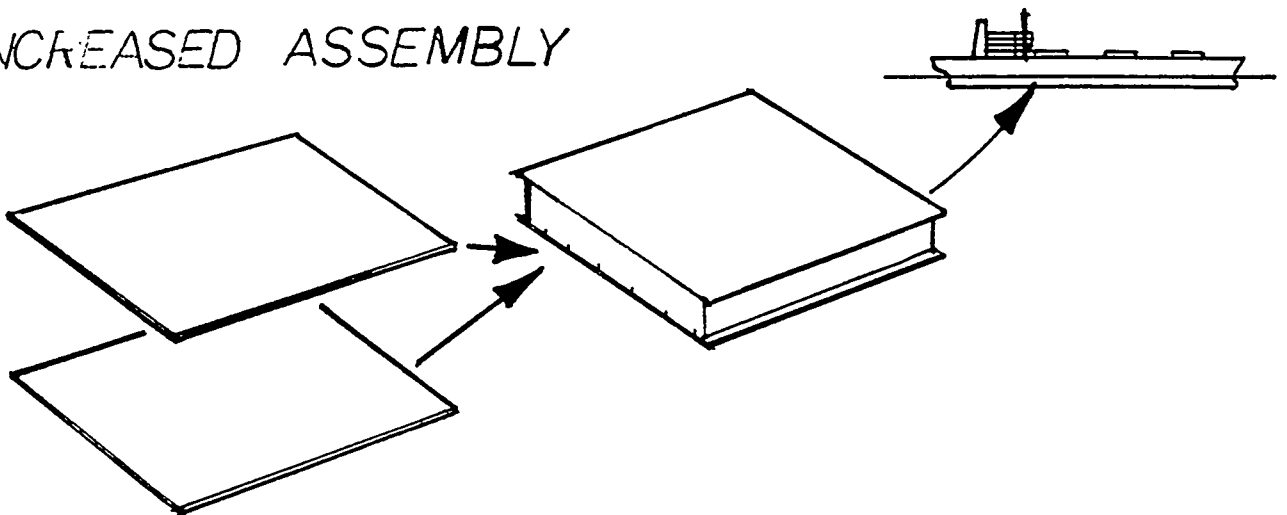
The former objective may be achieved through a policy of design rationalization and standardization, in order to enable design drawings and material specifications to be completed earlier.

The latter objective may be achieved through the adoption of a policy of carrying out as many production activities in parallel as possible. This will not only mean the overlapping of steelworking and outfitting activities but also the subdivision of the vessel in such a way as to enable the final erection cycle time to be reduced to a minimum. This means reducing the number of erection units and providing a number of work areas as early as possible. The same philosophy is then applied to the erection units themselves and to the subassemblies which make up the erection units. Outfitting work would be approached in the same way with as many outfit assemblies being produced as possible in order to reduce the time required for installation.

In the early days of steel fabrication, around 25% of the joint length was completed during erection consuming some 75% of the total steelwork manhours. Today, the more efficient shipyards use only 20-25% of their steelwork manhours during erection with up to 70% of steelwork manhours being used in the assembly of steel units. Thus, it may be said that modern shipbuilding is very much a matter of efficiently organizing the assembly processes. Similarly, in the past, outfitting work was essentially started after launch, whereas today's leading shipbuilders complete at least 80% of all outfitting work before launch.



*INCREASED ASSEMBLY*



### 2.1.10.3 Reduction of Product Cycle Time

The ship erection cycle time will be determined by the number of transverse and longitudinal joints that need to be welded at the erection stage and by the level of dimensional accuracy maintained during unit assembly.

As the number of erection joints decreases so the size of the units increases along with their work content. It is therefore important to further subdivide the units into sub-units, part units, subassemblies and minor subassemblies such that these may also be produced in parallel, thereby reducing the time taken to finish-assemble each unit as well as the time required from start subassembly to finish assembly. In this way the number of assembly work areas are increased, thereby allowing more work to be undertaken simultaneously while at the same time reducing the amount of work remaining at the unit assembly and erection stages.

A parallel approach may be taken with outfitting work. The first step is to complete as much of this work as possible prior to launch as open sky outfitting. However, since the erection cycle time has been reduced, it will be necessary to complete some of the outfitting work prior to erection. As the erection cycle time is further reduced it will be necessary to reduce the installation work content. This may be achieved by building outfit subassemblies and units. These actions are, of course, complementary as the opportunities for "on block" plus unit outfitting increase as the block size increases.

As the erection cycle is further reduced it may be necessary either to increase the time available for engine room outfitting by introducing semi-tandem erection methods or to increase the size of engine room steel units thereby enabling a higher degree of completion of outfitting work prior to erection.

Summarizing the above, the production cycle may be reduced by:

- overlapping the steel and outfit work cycles,
- reducing the steel work content at erection,
- reducing the outfit installation work content after erection.

In order to achieve these abbreviated production times and to ensure completion of all the work to be done at each production stage it will be necessary to provide appropriately detailed technical information and to install effective planning and material control procedures.

#### 2.1.10.4 Reduction of Pre-production Cycle Time

Research into the nature of design work performed in Sweden in the early 1960's, and covering a wide range of industries, showed that only about 10% of design work is truly innovative. The remaining work may be classified as the selection and use of standards of various kinds and the combination and modification of standards to meet a new specification or requirement.

The conclusion of this research was that the most significant improvement that could be made to the design process was the implementation of a means of improving the retrieval of standard design information. This would enable the designer to perform the selection, combination and modification of standard data more effectively. These findings are interesting since they exactly reflect the approach being taken by today's advanced shipbuilders.



The first step taken was to rationalize existing designs and hence develop a range of "standard" arrangements, each of which offered a limited range of detail variations, for example, choice of equipment suppliers or improvements in the specification.

Material Lists were then prepared for each of these "standard" arrangements and these were stored together with details such as equipment mounting data in such a manner as to provide a rapid means of data retrieval. The final stage was to establish computer files for this information and to link the whole to a CAD/CAM system and to the main planning and material ordering systems. As a result of these developments not only have significant reductions been made in the overall design period but also quite dramatic improvements have been made with regard to material ordering, with claims being made that up to 80% of material requirements may be ordered with only 30% of the design work completed.

The commercial advantages of achieving the claimed figures are clear advantages to be gained in production from the standardization of arrangements should not be under-estimated.

In view of the limited resources available it is probable that the adoption of the approach outlined above may prove to be the only way of providing the detailed information required to support the assembly method of shipbuilding coupled with short cycle times.

VOLUME 2

DESIGN/PRODUCTION INTEGRATION

PART 2

SHIP DESIGN STATES

2.2      SHIP DESIGN STAGES

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### 2.2.1 CONCEPTUAL DESIGN

The conceptual design stage establishes an overall outline design, to meet an owner's outline specification. It can also develop a marketable design as Part of a shipyard's product development. Although the main outcome is a design to meet specified mission requirements, some account can and should be taken of production requirements. At this stage the designer has considerable flexibility in his choice of dimensions and other parameters which define the vessel.

#### CROSS-REFERENCES

- . 2.1.1 Ship cost - Influence According to Design Stage.
- 2.1.4 Need for Formalization of Design Processes.
- 2.3 Ship Production.
- 3.2 Ship Geometry and Layout Engineering.

### 2.2.1.1 Introduction

The objective of the conceptual design stage can be stated to be:

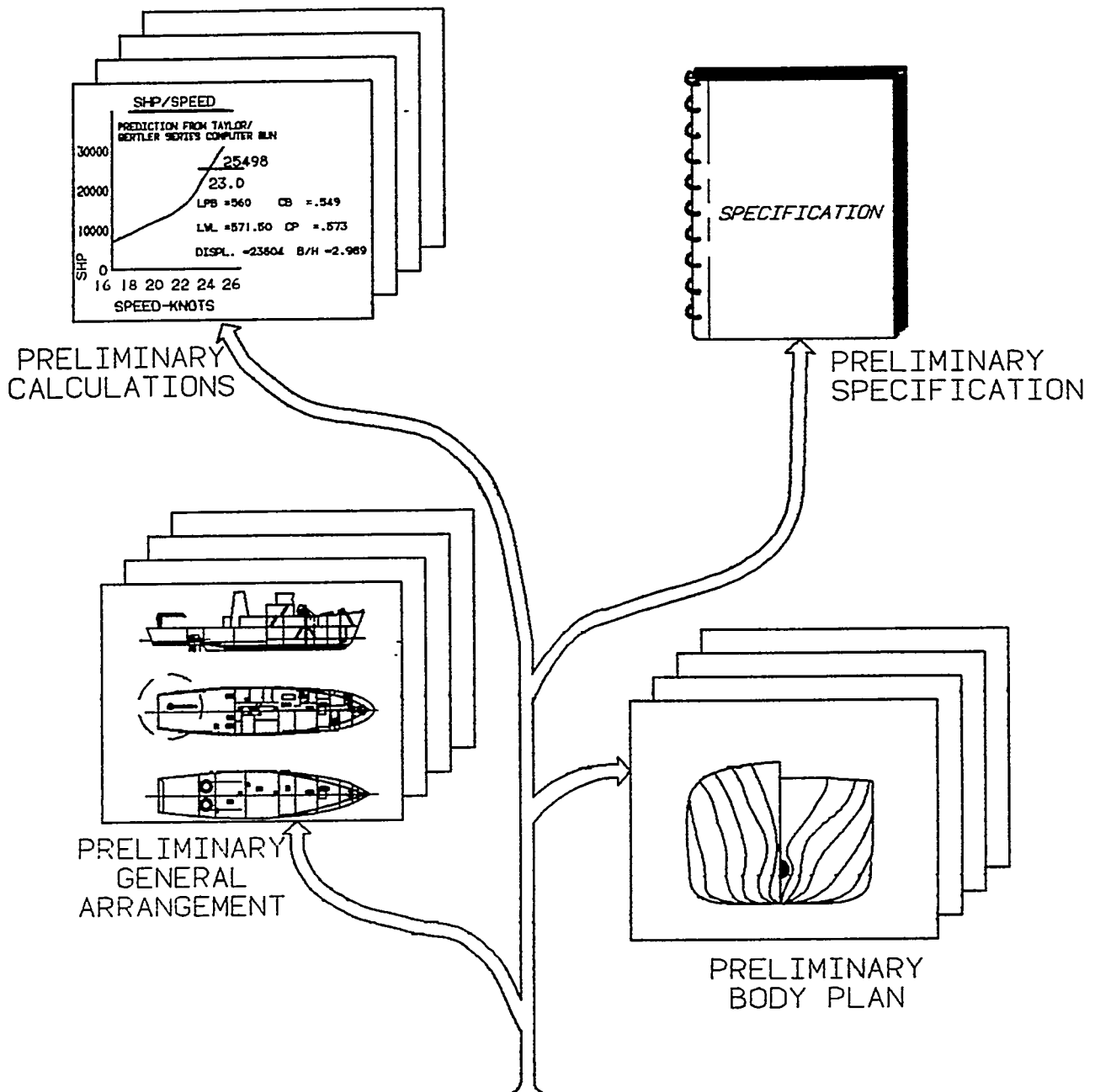
To establish overall features of a design to meet owner or mission requirements.

The content of the stage can be defined as a series of inputs and outputs. Inputs may be presented in the form of an outline specification, or one may be developed as a basis for the conceptual design. Inputs and outputs are listed below:

Inputs	-	Service requirements
		Routes
		Market forecasts
		Technical change in ship components and equipment
outputs	-	Preliminary general arrangement, midship section
		Preliminary specification
		Preliminary calculations (dimensions, capacities, etc)
		Preliminary body plan

If at this stage a shipbuilder has been identified, the following production inputs and outputs are essential:

Production Inputs	-	Shipbuilding policy: type plan facility dimensions interim product types
Production Outputs	-	Preliminary block breakdown Zone identification



## CONCEPTUAL DESIGN OUTPUTS

### 2.2.1.2 Hull Form

During the conceptual design stage the designer is guided by an outline specification produced by the owner or on information direct from market analysis. From this information the basic draft, length, depth and beam of the vessel can be developed which meet the specified cargo capacity, speed and range of the specification.

In developing the main dimensions, account must be taken of service restrictions, for example, canal restrictions on beam or port restrictions on draft. At the same time the capacity of various production facilities to build the design can be considered. This will not be a dominating feature, but should be a consideration.

The next step in the conceptual design process is the development of the preliminary body plan and the ship's lines. The location and spacing of main transverse, watertight bulkheads should now be established. Calculations concerning flooding and preliminary damage stability should be conducted.

Positioning the bulkheads will be dependent on cargo or other space requirements, and on flooding and stability requirements. At the same time, given the availability of a pipe plan, the bulkheads can be positioned to meet production needs (Chapter 3.3.1). By having available all the relevant information, the opportunity can be created to design a vessel which is both functional and producible.

By considering all of the possible demands on volume, the designer can avoid the situation where late changes or additions will result in the moving of bulkheads.

### 2.2.1.3 Preliminary Calculations

At this stage of conceptual design some estimation of the power required to drive the vessel has been obtained and power calculations should continue with the interjection of various hull forms. Estimates of vessel weight must be maintained at all stages in the development of the design. The designer should be aware of the placement of major machinery items and their effect on the balance of the vessel. Weight estimates are needed to establish stability, trim and list of the vessel, in addition to ascertaining the design deadweight of the ship. The basic weight calculations form the basis for estimating the cost of the vessel.

Although weight is an appropriate parameter for an initial cost estimate, it must be treated with caution (Chapter 2.1.1). A reduction in weight will reduce the relevant material cost, but will not necessarily reduce the production cost. In some circumstances it may result in a cost increase.

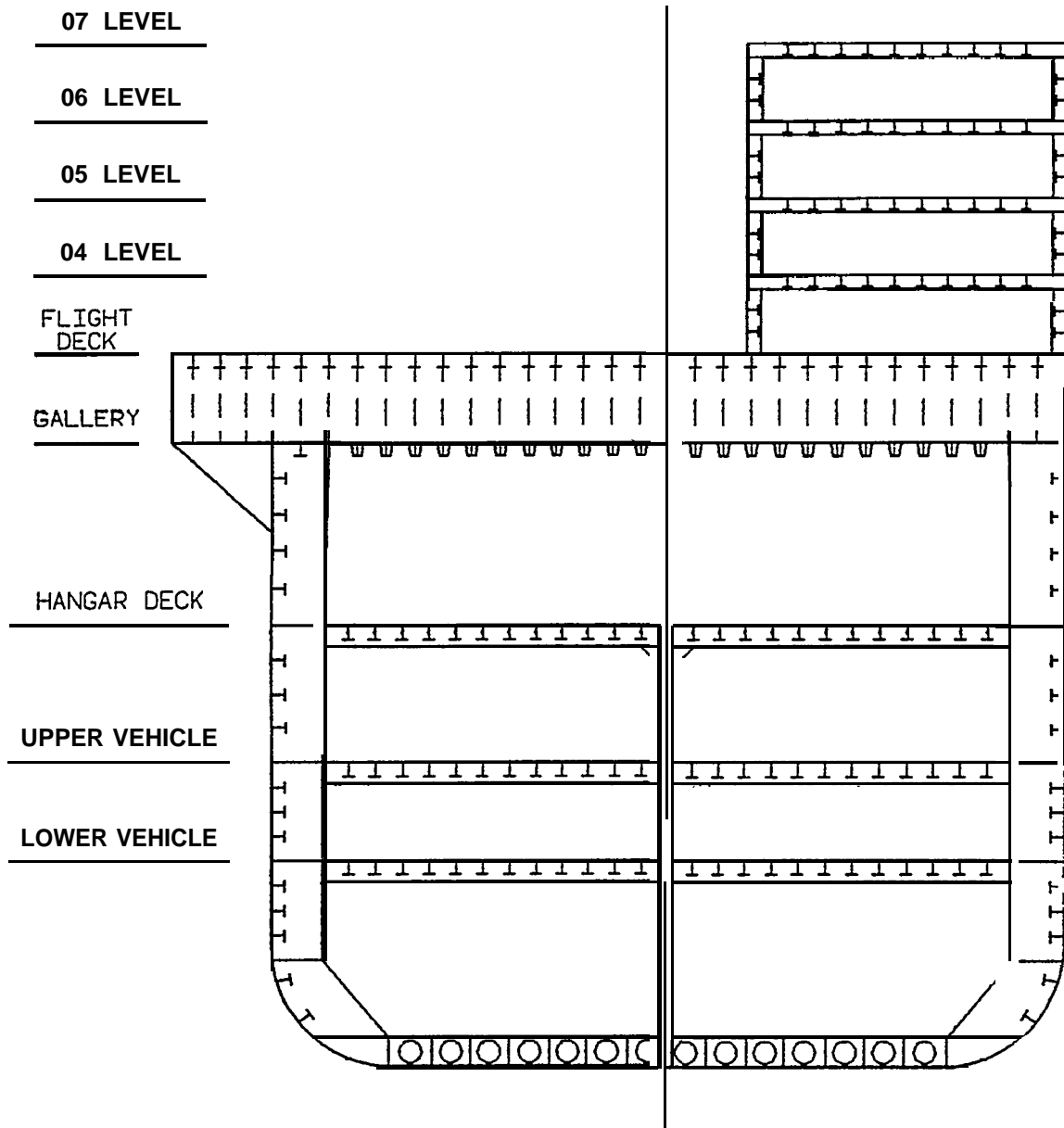


#### 2.2.1.4 Preliminary Arrangements

Accumulation of the foregoing information allows for the development of the preliminary hull and machinery arrangement drawings. Many items must be considered when developing the arrangement drawings for the superstructure, cargo spaces and machinery. The general arrangement is among the most important aspects of ship design as the operational efficiency and functional effectiveness is determined in this phase. Upon completion of the preliminary general arrangement a preliminary midship section is developed. Basic decisions pertaining to the location of framing must be made along with the establishment of the material **to be used** in certain areas of the vessel. Consideration should be given at this time to the standardization of frame spacing and the minimum use of shapes in order to simplify fabrication.

A typical midship arrangement is shown the opposite page.

At this stage the designer has considerable freedom to attempt innovative arrangements. As a minimum he should avoid the use of special fabricated shapes which inherently have greater work content than standard rolled shapes. If weight is a serious consideration, then an innovative approach based on more detailed structural analysis is required or, alternatively, a review of the main design parameters. Both are better than rigid applications of rules to a weight-sensitive design, with the result that there is a high variety of material sizes.



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### 2.2.2 CONTRACT DESIGN

The contract design stage establishes the features of a design in sufficient detail to provide the basis of a contractual arrangement. If the design is produced by a shipyard, producibility can be built in. If an external agency is involved, it is still possible to incorporate producibility through the use of standards, and by use of spatial analysis.

### CROSS-REFERENCES

- 2.1.1 Ship Cost - Influence According to Design Stage
- 2.1.4 Need for Formalization of Design Processes
- 2.3 Ship Production
- 3.1.6 Spatial and Process Analysis
- 3.2 Ship Geometry and Layout Engineering

### 2.2.2.1 Introduction

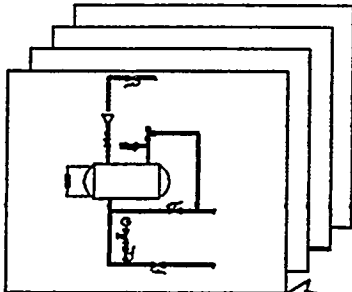
The objective of preliminary design is to establish the feature a design in sufficient detail to form the basis of a contract arrangement.

The stage can be defined in terms of a series of inputs and output. One major input will be the output from a conceptual design. main inputs and outputs are listed below:

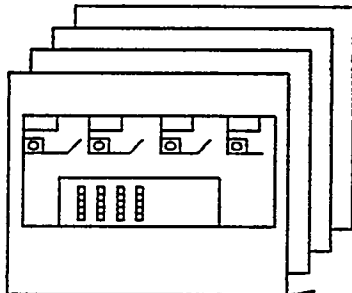
Inputs	-Conceptual design -Functional requirements -Regulations -Design standards
Production Inputs -	Shipbuilding policy Company standards and industry standards including: material sizes modules service runs block sizes spatial analysis
outputs	-General arrangement, midship section -Specification -Body plan -Ship calculations Propulsion calculations Accommodation arrangements Machinery arrangements Piping Diagrams Electrical load analysis Plan list
Production Outputs -	Preliminary build strategy: planning units Equipment identification. Long lead items Material requirements: quantities Long lead

HOT & COLD POTABLE WATER SYSTEM	00-1 (E2B)
SEWAGE & SLUDGE PUMPS	001-000 10-1 (E2B)
STRENGTH PLANCHES & HEAVY SPACE SPECIALISING SYSTEM	001-000 10-1 (E2B)
CHILLED WATER SYSTEM	00-24 (E2B)
ENGINE & GAS TURBINE AIR INTAKE & EXHAUST SYSTEM	001-000 0-1 (E2B)
SEA WATER CIRCULATING SYSTEM	006-000 1-1 (E2B)
BOILING PLANT PUMPS	001-000 10-1 (E2B)
LIQUEFIED GAS TRAILER PUMPS AND SERVICE SYSTEM	006-000 2-1 (E2B)
HEATING, VENTILATION & AIR CONDITIONING	010-000 10-1 (E2B)
WASTE HEAT RECOVERY SYSTEM	017-000 10-1 (E2B)

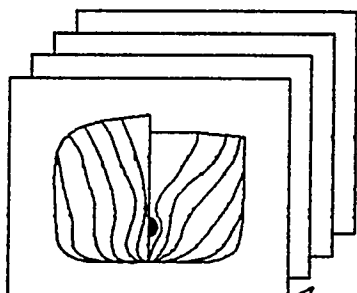
PLAN LIST



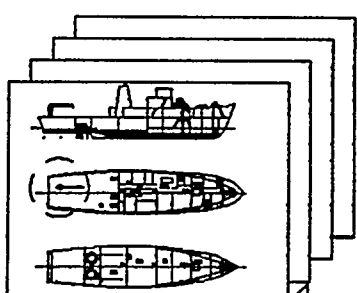
PIPING DIAGRAMS



ACCOMMODATION ARRANGEMENTS



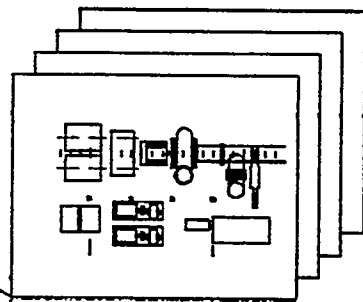
BODY PLAN



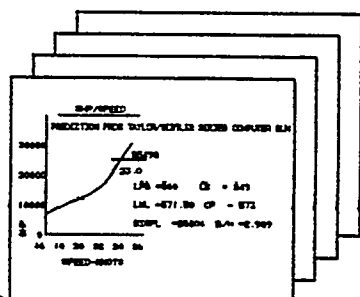
GENERAL ARRANGEMENT

SHIP ELECTRICAL POWER ANALYSIS				
POWER ANALYSIS OF SHIP SERVICE ELECTRICAL PLANT				
LINE	REV	NAME OF DEPT	ORIGIN	DATE
10	A	FEED PIP 1	30 1.05	30AP
20		FEED PIP 2	30 1.05	30AP
30	F	PRE-LINE PIP	10 .03	001P
47			10 .03	101P
50	C		20 1.05	101P
51	A		20 1.05	101P
60	A		30 1.05	101P
60	B		10 .03	

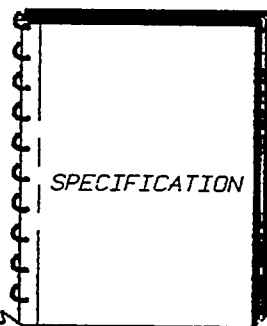
ELECTRICAL LOAD ANALYSIS



MACHINERY ARRANGEMENTS



SHIP CALCULATIONS



CONTRACT DESIGN OUTPUTS

#### 2.2.2.2 Preliminary Arrangements

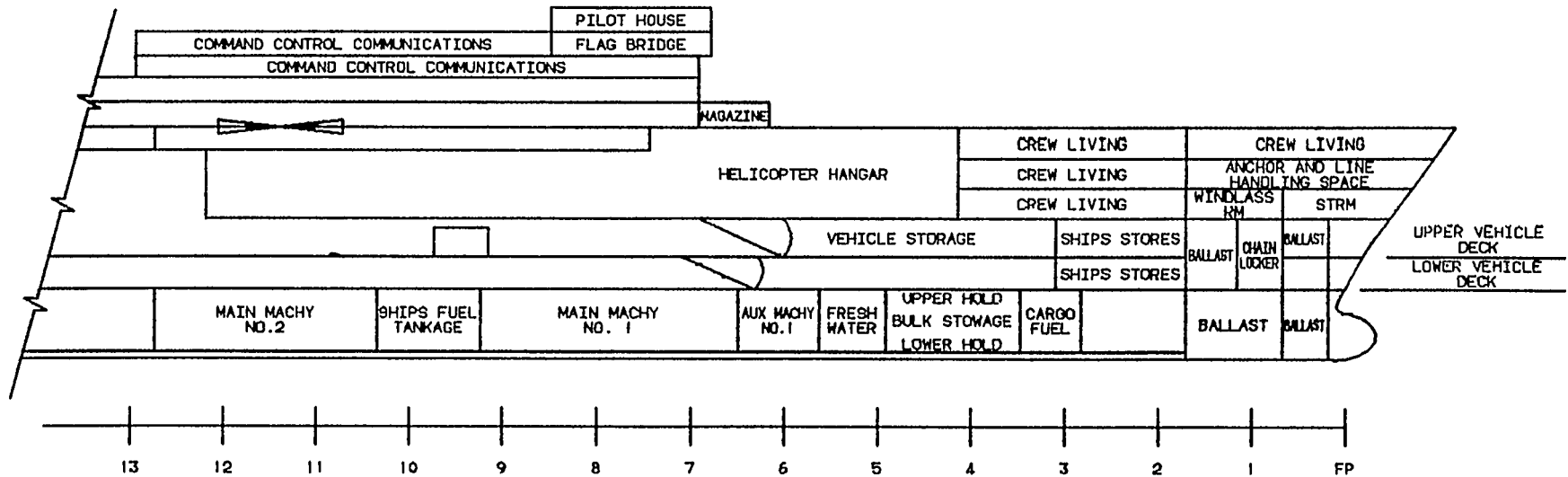
The purpose of preliminary design is to establish the features of the vessel design sufficiently clearly and completely so as to provide the basis for the contract.

The contract design phase utilizes the outputs established during the conceptual design phase and refines the functional requirements established in the owner's specification. The contract design phase establishes the basic key information necessary for all subsequent design phases. As the design continues to evolve and as engineering calculations are completed, information concerning the equipment becomes available. This information is incorporated into the contract specification and allows for the development of the machinery arrangement drawings, the accommodation and the hull general arrangements.

In developing the arrangements, there is considerable scope for influence on producibility. The designer has an opportunity to reduce ship cost by use of spatial analysis. This form of analysis looks at the ship not as a set of systems but as a set of functional spaces. A functional space is a specific volume within the ship which contains functionally interrelated equipment. The functional space is defined initially in terms of its circumscribing envelope rather than as the sum of its individual elements. Detailed internal design and precise locations are left to a later design stage provided only that it is certain that sufficient space is available.

Service routes can be treated in the same manner. The designer allocates volume to a series of main and secondary routes. Only a minimum necessary number of checks on the adequacy of the route cross sections is made. In addition, the priority of the distributive systems should be examined and rearrangement of compartments made where possible to simplify routes, reduce run lengths and simplify installation.

# PRELIMINARY ARRANGEMENTS FUNCTIONAL SPACE ALLOCATION





#### 2.2.2.3 Hull Form

The development of the design may result in revisions to the hull form. These may be minor, to take account of small variations in weight distribution, or could be significant, involving a change in one of the main dimensions.

The hull form should conform, as far as is practicable, with the requirements of producibility (chapter 3.2.1). As with the whole design for production topic, the emphasis should be on taking production needs into account as an input to the design process. Design for production is not a matter of minor adjustment to a design which is already established.

#### 2.2.2.4 Structure

A revised midship section will be produced, along with scantling plans. These will be produced in a format to suit classification or other approval bodies, but will not yet be fully developed to approval standard. In the case of novel or unusual features, preliminary discussions will be held. As far as possible standard features will be used in the development.

Production input to this stage of structural design is of great value.

The location and spacing of the principal structural members should be discussed with production, who can advise engineering of the spacing which best suits the production process. The designer should also be guided by production in the selection of the material size and weight used. Production input will assure that the material selected is compatible with equipment used in the production process. Without production input the designer could identify material for purchase, which otherwise could be produced from plate on existing yard equipment - example "T" beams. Another example would be the selection of material which did not lend itself to the "frame bender" and therefore would require "furnacing" which would increase manhours and cost.

#### 2.2.2.5 Ship Systems

Calculations pertaining to various piping, electrical and HVAC systems should be developed and specifications written for each. This information will guide the designer in the development of piping and HVAC diagrams and one line electrical drawings, and will provide the baseline for future activities. It is important to note that vendor information would be required in order to develop some of the more complex system diagrams.

Functional space allocation is applied in the determination of service routes, both horizontally and vertically to suit the machinery arrangement. These preferred routes encourage the use of pipe banks and the use of pipe standards at a later stage.

Development of the system diagrammatics is also carried out in stages. In a way similar to the machinery arrangement, the power requirements are considered and main and auxiliary power generators are defined. When this is done, a flow diagram showing the connections between the main and auxiliary equipment is drawn for each system. This flow diagram does not show capacity or diameters but takes account of the functionality of the system.

The capacity of each of the major components is then determined and provides the basis for the technical specification. This will identify all the necessary information, as for example voltage, capacity, and pressure together with any other relevant information which influences the choice of item.

From this the flow diagrams are developed to give a preliminary insight as to the pipe diameters, pump capacities, pressure and valve types for all connected equipment. This allows the specification of all items not previously specified to be developed.

#### 2.2.2.6 Drawing List

Once all the systems within a vessel have been identified and the structural arrangement has been established, a preliminary drawing list should be developed.

In parallel with the design development a preliminary build strategy will have been developed. This will identify the planning units, structural units, outfit assemblies and zones based on functional spaces, which make up the vessel.

Two sets of drawings which will be required can now be listed. Conventional drawings will include all approval drawings, and those which define the ship from a functional standpoint. In addition, a set of production drawings will give all the necessary production information for manufacture, assembly and installation, related to each planning unit. The format of production drawings is discussed later in chapter 2.2.7.

The drawing list should form part of the contractual arrangements. Who is to produce each piece of information, and when, should be specified (chapter 2.2.6). Where a design subcontractor is utilized this becomes especially important to insure that a complete and early definition of the drawings be produced.

### 2.2.3 FUNCTIONAL DESIGN

Functional design is the stage that follows contract signing. Its objective is to develop a design to the point where classification and "other approvals" can be obtained." It also establishes specifications for all materials and equipment. Whereas previously the design may have been developed remotely, it must now be integrated with production, not only in engineering but also in planning to ensure information and materials are available when required.

### CROSS-REFERENCES

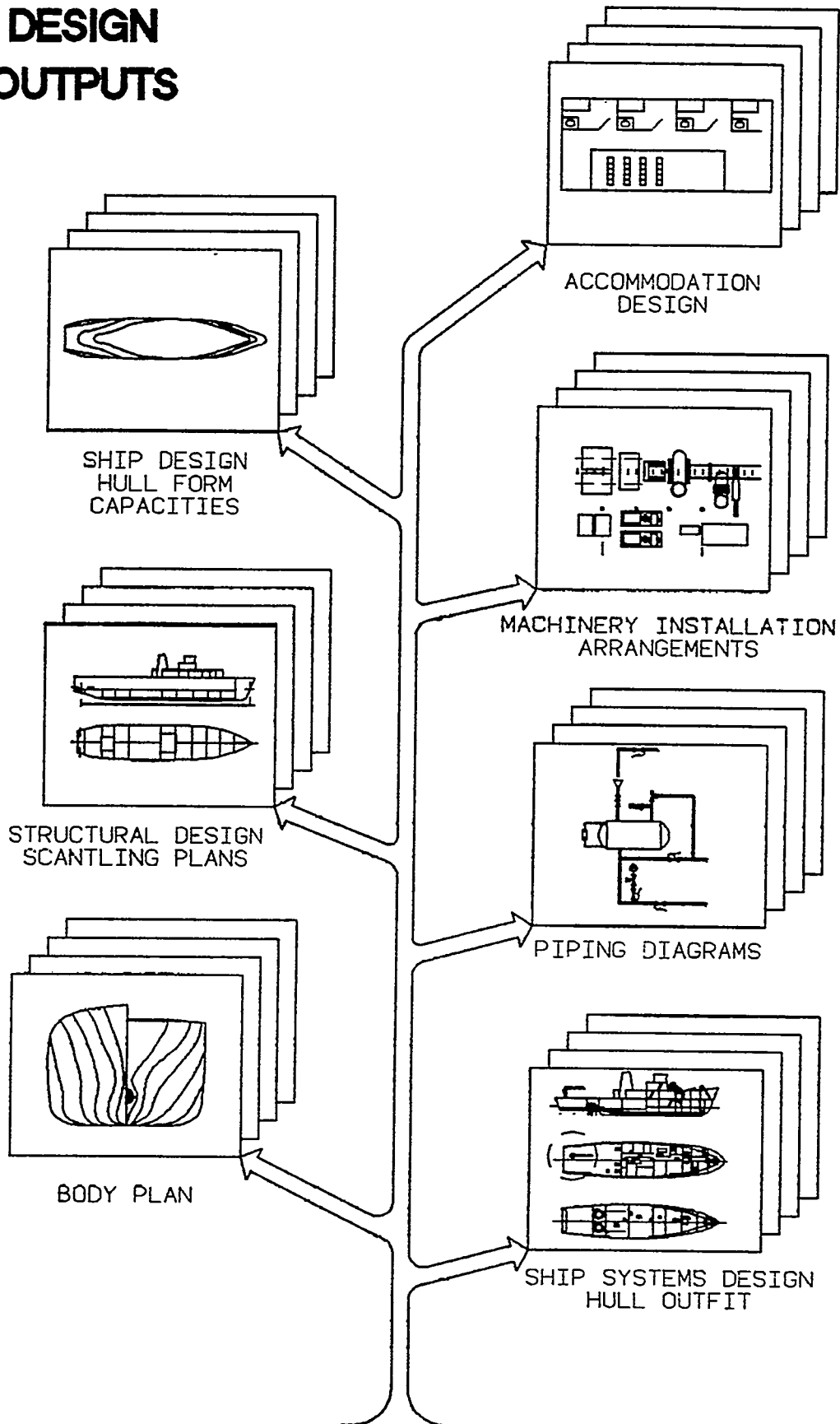
- |      |   |
|------|---|
| 2.11 | Ship cost - Influence According to Design Stage |
| 2.14 | Need for Formalization of Design Processes      |
| 2.3  | Ship Production                                 |
| 3.2  | Ship Geometry and Layout Engineering            |

### 2.2.3.1 Introduction

Functional design follows contract signing and is intended to establish features of a design for the purposes of classification and other approval and material specification. The various inputs and outputs are listed below:

Inputs	Contract design Functional requirements
Production Inputs -	Preliminary build strategy Standards Production Processes Facilities
outputs	Ship design: hull form capacities, etc Structural design: approval drawings, scantling plans Machinery installation: arrangements piping diagrams electrical fittings, etc Accommodation design Ship systems design Hull outfit
Production Outputs -	Contract build strategy Schedules: erection/installation assembly. manufacture Production information Purchasing information

# FUNCTIONAL DESIGN OUTPUTS



#### 2.2.3.2 Naval Architecture

The functional design phase establishes the features of the vessel through the refining of the preliminary design. The hull form is finalized, on the basis of any performance assessments including model tests. The form is faired in order to develop the shell plating, and to prepare offset information for the accurate definition of the ship structure.

Final space allocations are made for all tanks, storage areas, cargo spaces, utilities and living spaces. Final trim and stability calculations are made. Overall the ability of the vessel to perform its missions is verified.

### 2.2.3.3 Structure

The structural arrangement of the vessel is finalized and all the drawings and other information necessary for regulatory approval are made. Production input during the functional design stage will provide for the incorporation of shipyard standards into the design of the vessel. The structural arrangement should take account of the assembly sequences proposed in the preliminary build strategy. This will ensure that maximum use is made of downhand welding and that work is completed as early as possible in the overall ship production process. Standard frame spacing and the use of materials which best suit the protection process should also be incorporated (Chapters 3.2.2 and 3.2.5).

Emphasis should be placed on providing the minimum information compatible with satisfying the regulatory bodies. As much of the information as possible, for example, bracket connections, cut-outs and slots, should be in the form of references to standards.

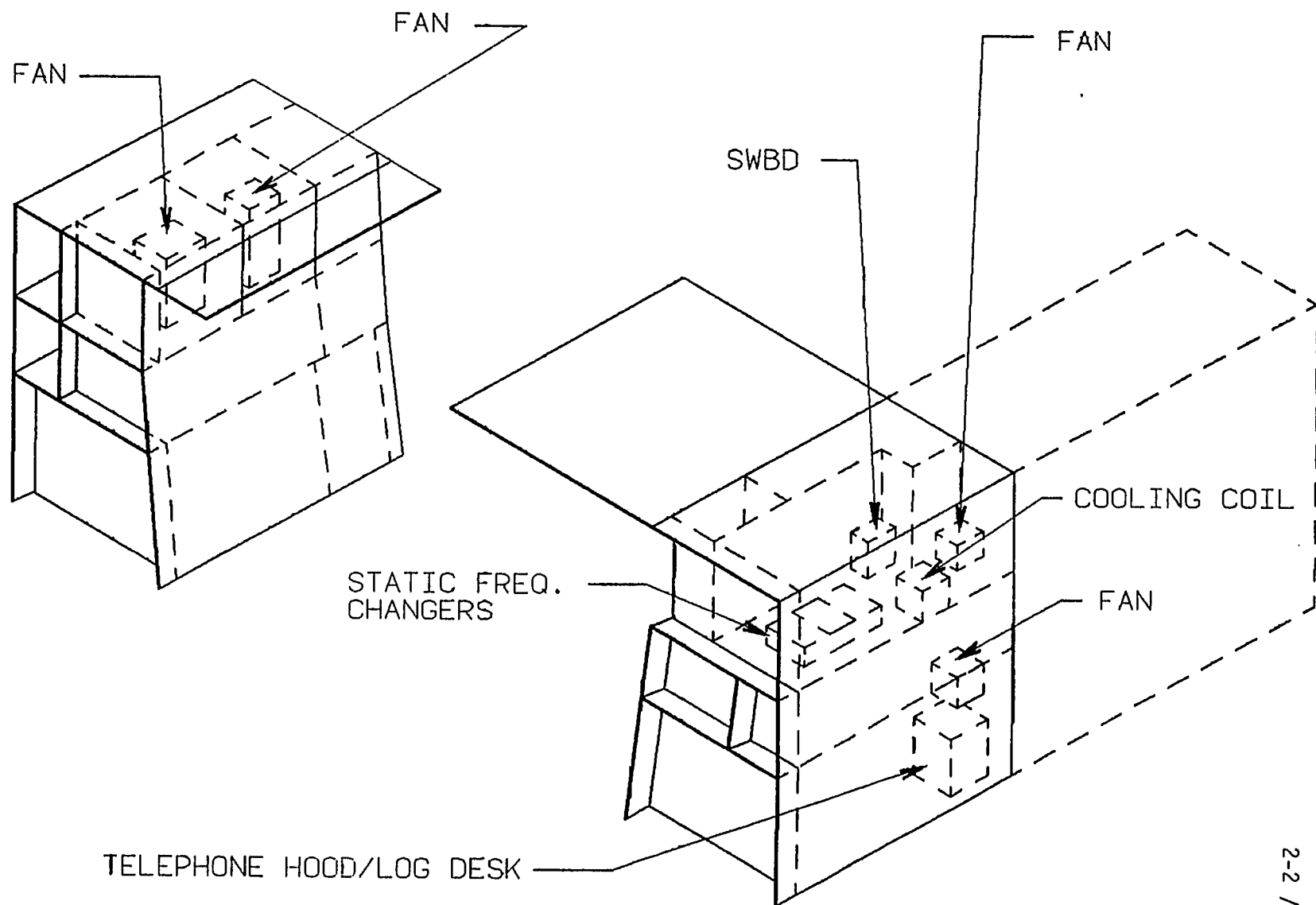
In all cases the format of the information should itself be standardized. It may well be essential to hold discussions with the regulatory bodies at this or earlier stages to ensure that all parties understand and accept the proposed information formats.



#### 2.2.3.4 Machinery Installation

The machinery arrangement is developed using only as many views as necessary to identify compartments, tanks, locations of main and auxiliary equipment and services routes. Once again, the criterion will be minimum detail. All the information to be produced should have been analyzed to identify its purpose and then to decide how little can be provided to satisfy that purpose. Except in special cases where it is known that there is high intensity of equipment, only the spatial envelope is needed (Chapters 3.2.3 and 3.2.4). Some representation of the machinery space showing the equipment as outlines and incorporating plan and sectional views is generally provided.

From the contract piping diagrams final arrangements are developed.



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#### 2.2.3.5 Hull and Accommodation Outfit

The requirements of this stage are to satisfy regulatory bodies of the vessel's ability to function. In general, detailed drawings are not needed, nor are dimensionally accurate drawings needed in most cases.

In both hull and accommodation, the designer will locate equipment and make arrangements such that erection butts are clear of complex spaces. This will assist with the application of advanced outfitting.

#### 2.2.3.6 Planning Involvement

The hull structure scantling plans will be used for a process analysis of the various units thus identifying the number of assembly types contained within each block and the method of fabricating and assembling each unit. Similarly, an analysis of the transition-design will identify the outfit content and the preferred method and stage of installation.

Review of this information will allow the identification of material requirements by planning unit. This will allow the development of the build strategy complete with method descriptions.

The development of the contract build strategy provides the basis for a more detailed drawing program to be prepared together with the scheduling of material requirements, manufacturing shops and assembly shops.

#### 2.2.4 TRANSITION DESIGN

Although it is identified as a separate stage here, partly to assist in its definition, transition design in many ways pervades the complete design process. Transition design shifts the focus from a system orientation to a planning unit orientation. Thus spatial analyses or a type plan are part of transition design, at an earlier stage.

The main emphasis is on developing work packages from the contract design information. These work packages are then detailed at the detail design stage.

#### CROSS-REFERENCES

- 1.2.3 Modern Shipbuilding Objectives
- 2.1.10 Implication of Short Lead Time
- 2.11 Ship Cost - Influence According to Design Stage
- 2.14 Need for Formalization of Design Processes
- 2.3 Ship Production
- 3.2 Ship Geometry and Layout Engineering
- 3.3 Shipbuilding Policy

#### 2.2.4.1 Introduction

Transition design is considered here as a distinct stage, although in some aspects it runs parallel to the functional design process through all the stages.

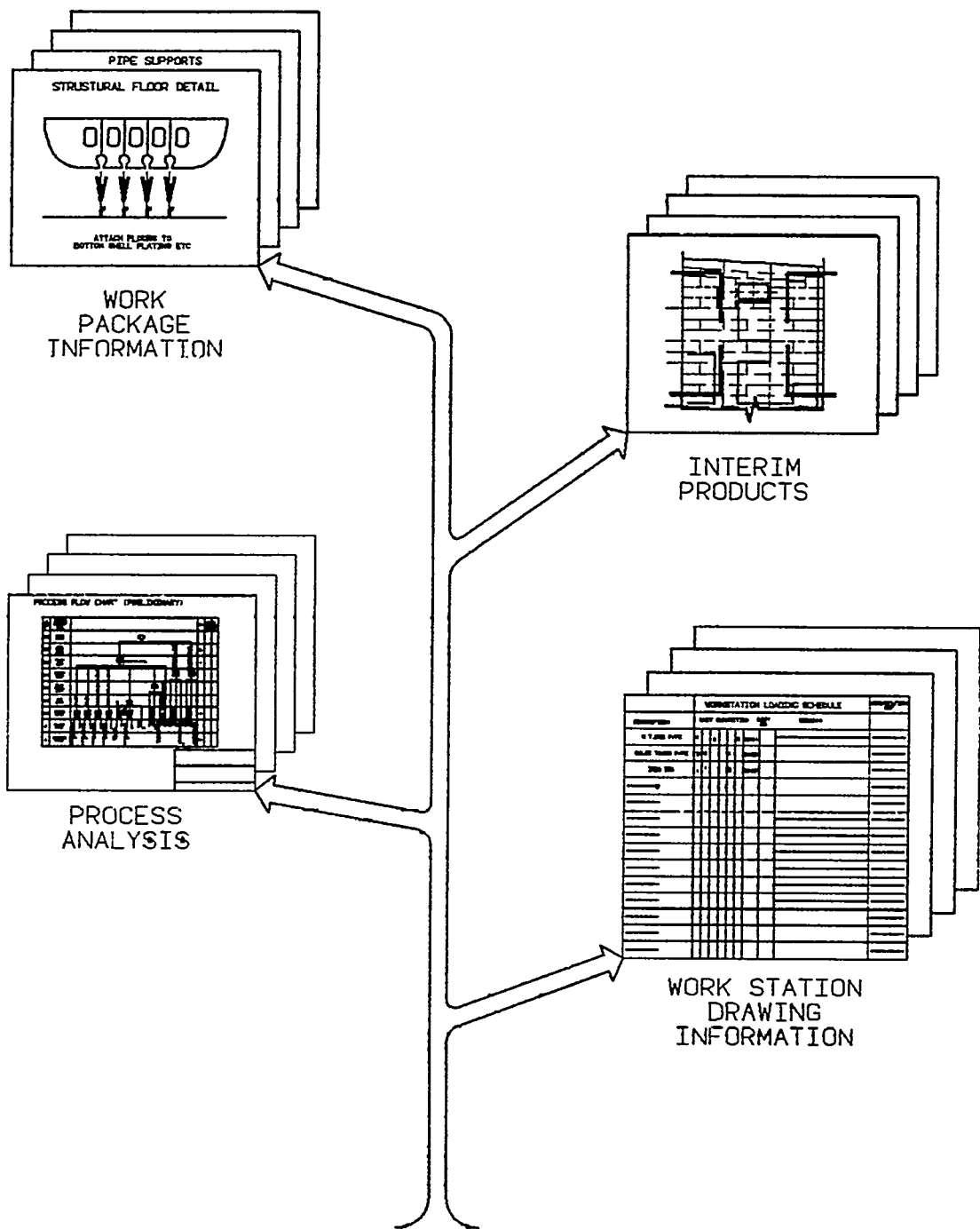
The objective of transition design is to translate the features of the design from the system orientation, necessary to establish functional performance, to a planning unit orientation, necessary to establish production requirements.

Transition design develops elements of systems into steel and outfit zone composites. It should be based on the spatial analysis of earlier design stages.

However, for effective design for production to take place, production needs and capacities should be highlighted from the earliest stage:

Inputs	Conceptual design Contract design Functional design
outputs	Process analysis Interim products Work package information Work station drawing information

# TRANSITION DESIGN OUTPUTS



#### 2.2.4.2 System Integration

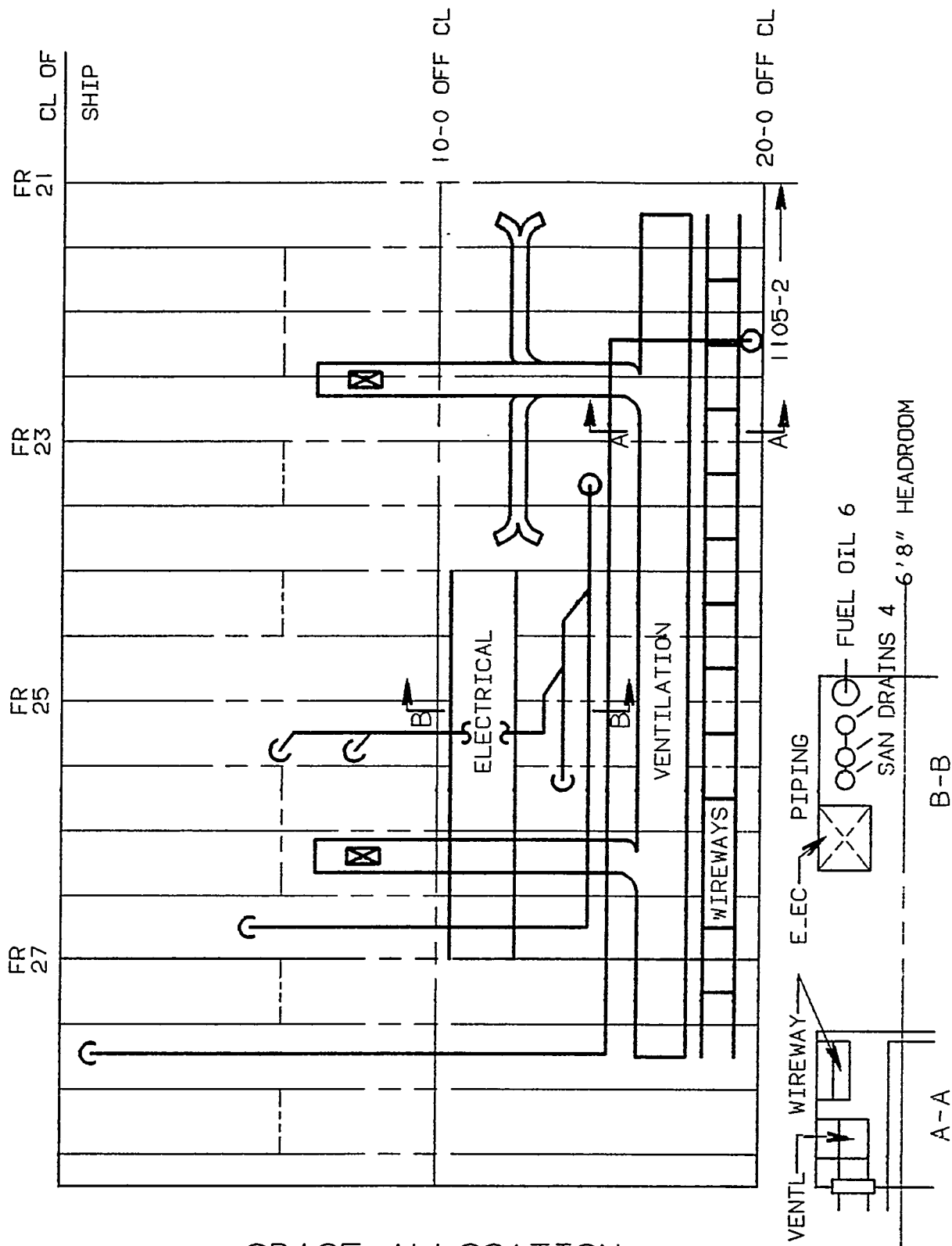
During the functional and contract design stages the parameters of each planning unit have been developed. If the principles proposed in this manual have been implemented, then much of the outfit content of the vessel will have been assigned to an outfit assembly. The ship's systems will have been allocated routes. The routes will be consistent with steel unit breaks. At the same time system diagrams will have been developed which indicate the links between system elements and the pipes, cables and HVAC runs required.

It is now necessary to integrate all system diagrams for each steel unit and for all system routes. The integration of systems results in a composite drawing which shows all the systems in any planning unit. The internal arrangement of outfit assemblies is left to the detail design stage.

The piping, electrical and ventilation systems passing through each particular planning unit must be identified and space allocated for each system. This approach requires a concentrated effort, but will establish a better design and one that is production oriented. The integration step establishes the location of each pipe in relation to other systems within the predetermined route, and allows for the development of pipe banks. As the integration process continues it may be evident that the design can be improved by the relocation of equipment which would further simplify the pipe run and improve the pipe bank concept. The time and effort spent in integrating the diagrams will reward production by reducing the number of fittings required. Since all systems have been integrated one system is not trying to cut across the path of another. In tight spaces the integration process may show that certain systems would be better run in another route thus again simplifying the design. The priority of one system over another must be emphasized and uniform guidelines developed for all designers.

This same approach should be used in machinery spaces, particularly under floor plates. Integration of the diagrams will establish the best possible location for each system traversing the lower machinery space and will eventually lead to the development of pipe banks integrated with the grating supports and foundations. Integration of diagrams establishes the location for each piping system and removes the problem of having a small diameter pipe designed into a prime location that would be better suited for a large diameter pipe. This avoids the situation where the large diameter pipe requires a larger number of fittings and difficult welds to reach its destination. The integration of machinery space diagrams will also point out producibility problems caused by the machinery arrangement which can be alleviated by relocation of the machinery.

Passageways are also distributive systems. Not only do they provide for movement of personnel, but also they provide access for repair and maintenance.



# SPACE ALLOCATION DIAGRAM INTEGRATION

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#### 2.2.4.3 Process Analysis

The shipbuilding policy will include information on the preferred processes to be used in the shipyard (Chapter 2.3.3). This information will have been developed to form part of the "contract build strategy. For each planning unit the sequence of work and the installation activities to be carried out at each stage in the sequence will have been identified in outline. The plan list for the contract will be based on this preliminary analysis and modified, if necessary, at the functional design stage.

In the case of steel planning units, each is broken down into a hierarchy of smaller assemblies. The lowest level is the raw material which is cut and formed to produce parts. These are then combined in the various stages of assembly, which are:

- piece parts
- minor assemblies
- subassemblies
- units
- blocks

These stages may be further sub-divided, or combined, to suit particular production facilities.

The identification of all the steel items at each stage is shown in the figure. This shows the sequence of work from parts to the finished planning unit. Each item, at each stage, will be the subject of detail design, and will have one or more work station drawings to define it for production.

Outfit planning units consist of zones and outfit assemblies. The outfit assemblies are analyzed in a similar manner to steelwork. A number of stages in the building of an assembly can be identified, and a hierarchy of interim products can be developed. The stages are:

raw material parts minor assembly subassembly	These stages normally involve a single craft for any one interim product.
outfit assembly outfit unit outfit block	These are normally multi-craft interim products.

As in the case of steelwork, these stages may be combined or further sub-divided to suit particular production facilities. The interim products identified at each stage will be developed during detail design. Each product will be defined by work station drawings. Where more than one craft is involved, additional drawings may be required.

Zones present the most complex analysis problem.

Installation can be carried out at a number of stages before the ship is erected:

Subassembly - adding outfit parts to steel subassemblies.

Subunits - for example, deckhead outfitting.

Units.

Block.

Installation on the ship includes:

Installation prior to completion of hot work.

Final installation after hot work.

Installation can be carried out before launch or after launch:

Prior to functional trials.

After sea trials.

The installation can be of outfit interim products at any of the assembly stages, and may involve several trades. The figure shows the analysis of a simple case.

All the outfit items have been identified, and the appropriate installation stage for installation determined. The zone number is C14, but for those items which will be installed before the ship is constructed, the steel planning unit must also be identified. The outfit items must then be included in the analysis of the steel unit.

SHIP NUMBER 567																	ZONE C14				PROCESS ANALYSIS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
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Utilizing the preliminary analysis and plan list for the planning unit a "flow diagram" is constructed which identifies what systems and equipment will be installed on each structural component of the unit and at what point in the structural assembly of the unit.

Each step with the flow diagram is identified as a stage. A stage defines a package of work which can be coordinated with others in such a way as to avoid removal and reinstallation of previously installed work. Each work package should be separated by craft, except in cases where a reasonable amount of work is not produced and then crafts can be combined.

Since each unit and facility is different, no set plan exists for the development of work packages within a given planning unit. They should be sequenced to take advantage of downhand installation. Downhand installation eliminates overhead welding and the need for staging. Foundations which attach to the overhead should be installed while the structural component is in the downhand position. It is important to identify certain non-outfitting activities such as sandsweeping and painting and roll-over of structural assemblies.



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#### 2.2.5 DETAIL DESIGN

Detail design is the final stage in the design process. It is different from the traditional design process in that it is carried out by planning unit, rather than by system. The final output is a set of production information for work packages each of which represents a phase or stage in the production of a planning unit.

#### CROSS-REFERENCES

- 2.11 Ship cost - Influence According to Design Stage
- 2.14 Need for Formalization of Design Processes
- 2.3 Ship Production
- 3.2 Ship Geometry and Layout Engineering



#### 2.2.5.1 Introduction

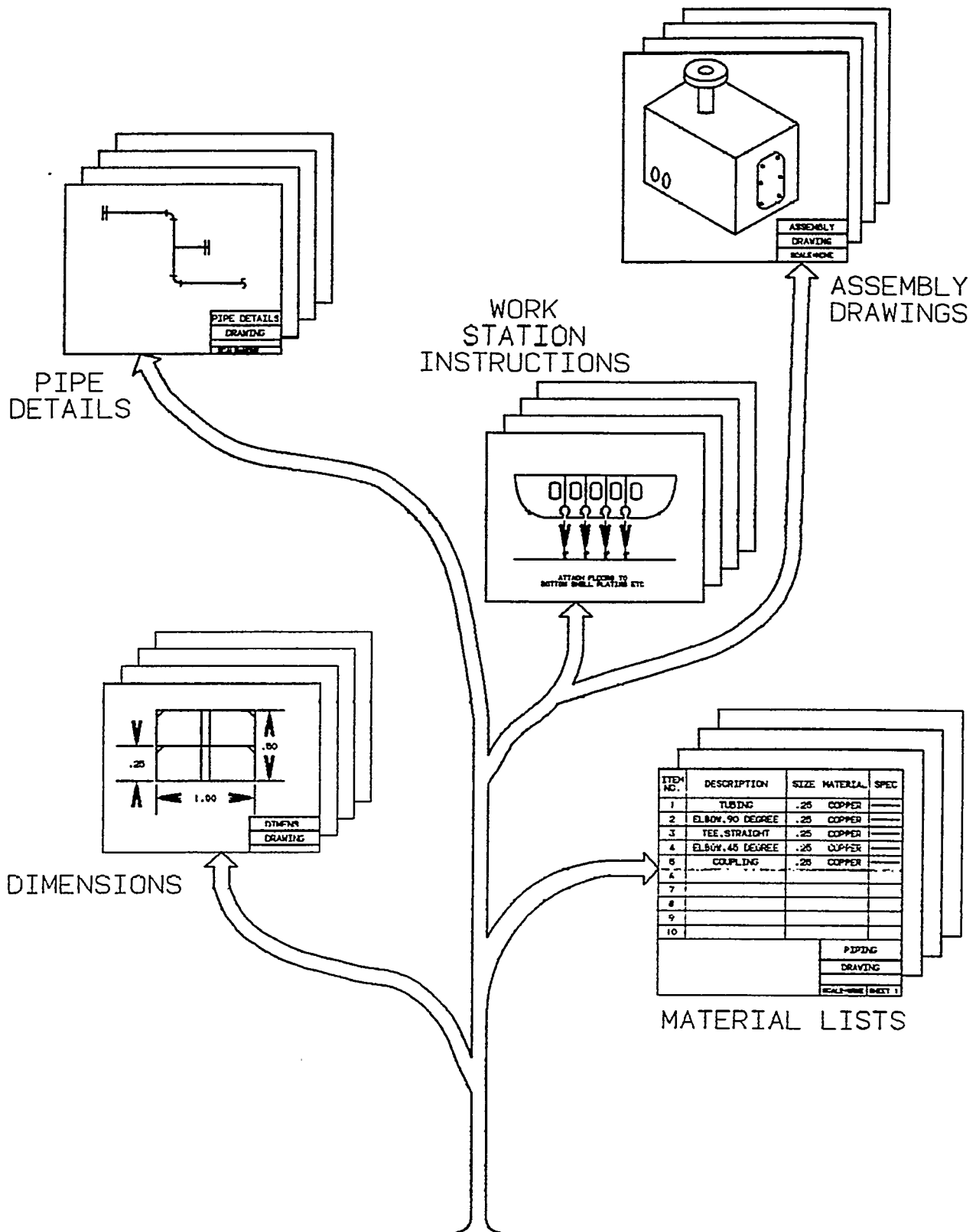
The objective of detail design is to establish the features of the design necessary to allow local purchasing, part manufacturing and subsequent assembly to be carried out.

Detail design is carried out by planning unit, on those elements of the ship which have been developed to the stage where all functional and approval requirements have been satisfied.

It can be defined in terms of inputs and outputs:

Inputs	Functional design
	Transition design
	Build strategy
	Standards
	Work station capacities
	Process analysis
outputs	Work instructions
	Work station drawings
	Material lists
	Dimensional requirements

# DETAIL DESIGN OUTPUTS



### 2.2.5 2 Scope of Detail Design

Detail design establishes the features of the design necessary to allow local purchasing, part manufacture and subsequent assembly to be carried out. The previous design stages have established the vessel in functional terms. All the items of equipment have been identified and required quantities of raw materials such as pipes have been established.

In parallel, the planning units which form the basis of the ship production program have been established. Each planning unit has been analysed to establish assembly and installation stages, and the work to be done at each stage has been determined. This forms the basis of work packages.

Detail design produces the information necessary to produce each work package. The precise content of the detail design stage will be dependent on the production system of the shipyard, which will determine the requirements for drawings and other information.

The planning units will have been established and the designer will be establishing pipe breaks, ventilation and wireways to suit the unit breaks. If make-up pieces between units are required the designer should also be identifying the dimensions of the make-up pieces and applying some type of identification. During the detail design phase the designer should standardize as many items as possible and should make use of shipyard and industry standards whenever possible (Chapter 3.2.6). Production input is still valuable during the detail design phase (Chapter 2.1.1). Production can advise engineering as to the design of hangers, brackets, wireways which best suit the production process or of existing standards utilized by production which may be applicable to the condition the designer has encountered.

During the detailed design phase the designer is finalizing the material list and quantities for each planning unit. Using unit breaks and transition drawings as a basis, structural details, material lists and fabrication instructions are developed to support individual yard capabilities bounded by each unit. If outfit assemblies have been identified the designer must develop production drawings which incorporate the various systems, foundations and structure into the outfit assembly design. All material should also be identified for the assembly. If it fits within a steel assembly a reference on the assembly drawings should identify the fact that an outfit assembly drawing exists so production will not install systems which are already incorporated on that outfit unit.

The detail design will identify and supply the necessary information for the fabrication of foundations. The foundation location should not be across steel unit breaks unless totally unavoidable as this would require that it could only be installed after two units had been completely joined aboard the vessel. Of course this condition might also require the addition of back-up materials on the underside of the decks. This would require staging, overhead welding, etc, all of which could be hindered by the systems which were installed in the advanced outfitting stages.

### 2.2.5.3 Work Package Drawing Development Example

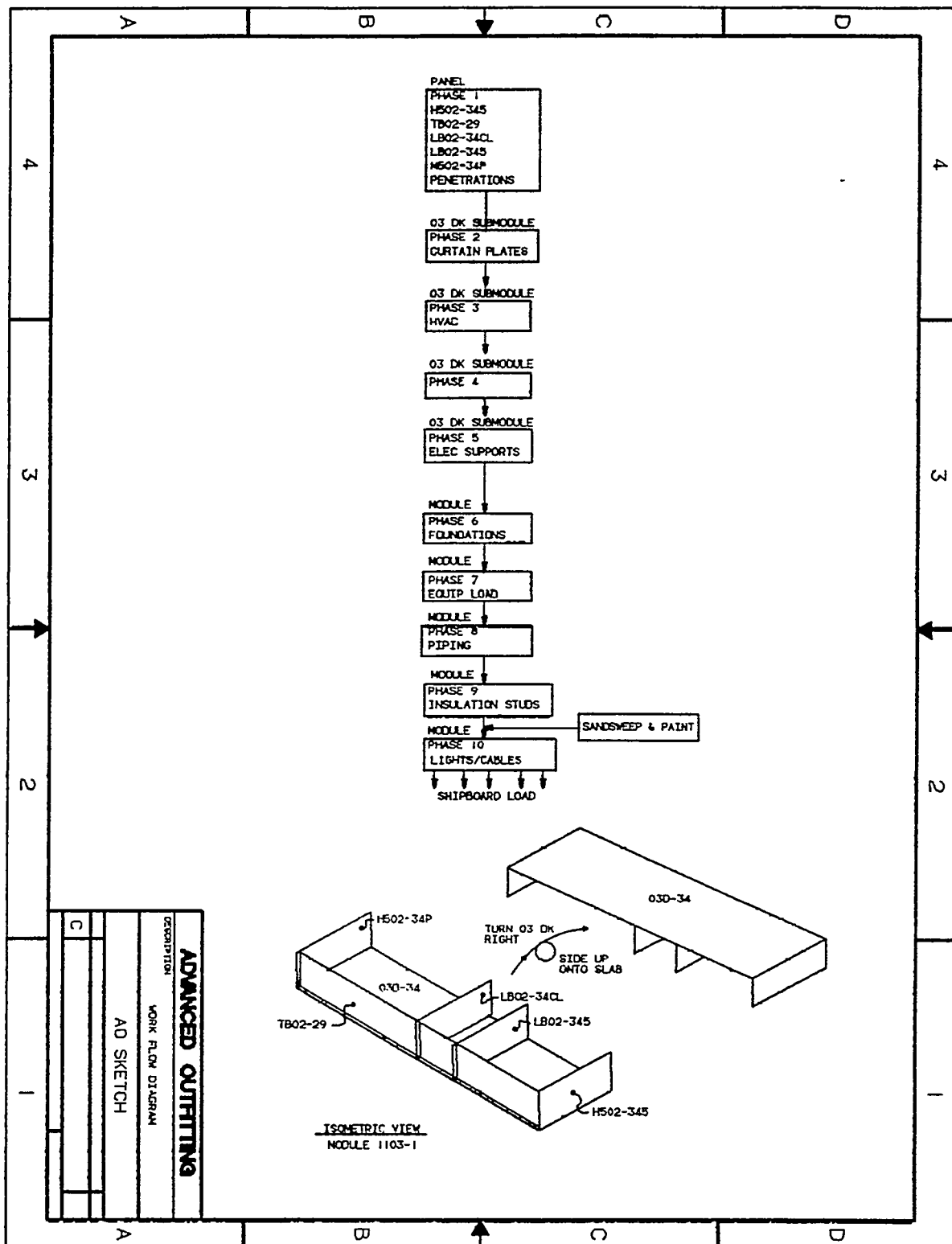
The process analysis for each planning unit will have resulted in a simple isometric drawing showing assembly procedures. A flow diagram identifies the sequence of assembly and installation.

For each stage in the sequence, and where appropriate to each craft, a specific production drawing is developed. The drawing format will vary according to facility and production methods. An example of a series of drawings is described in the rest of this chapter. The example covers the outfit items to be installed on a particular steel unit, but the principles outlined would apply to any planning unit at any stage.

( Further examples of the output of detail design are shown in Chapter 2.2.6 - Format of Engineering Information.)

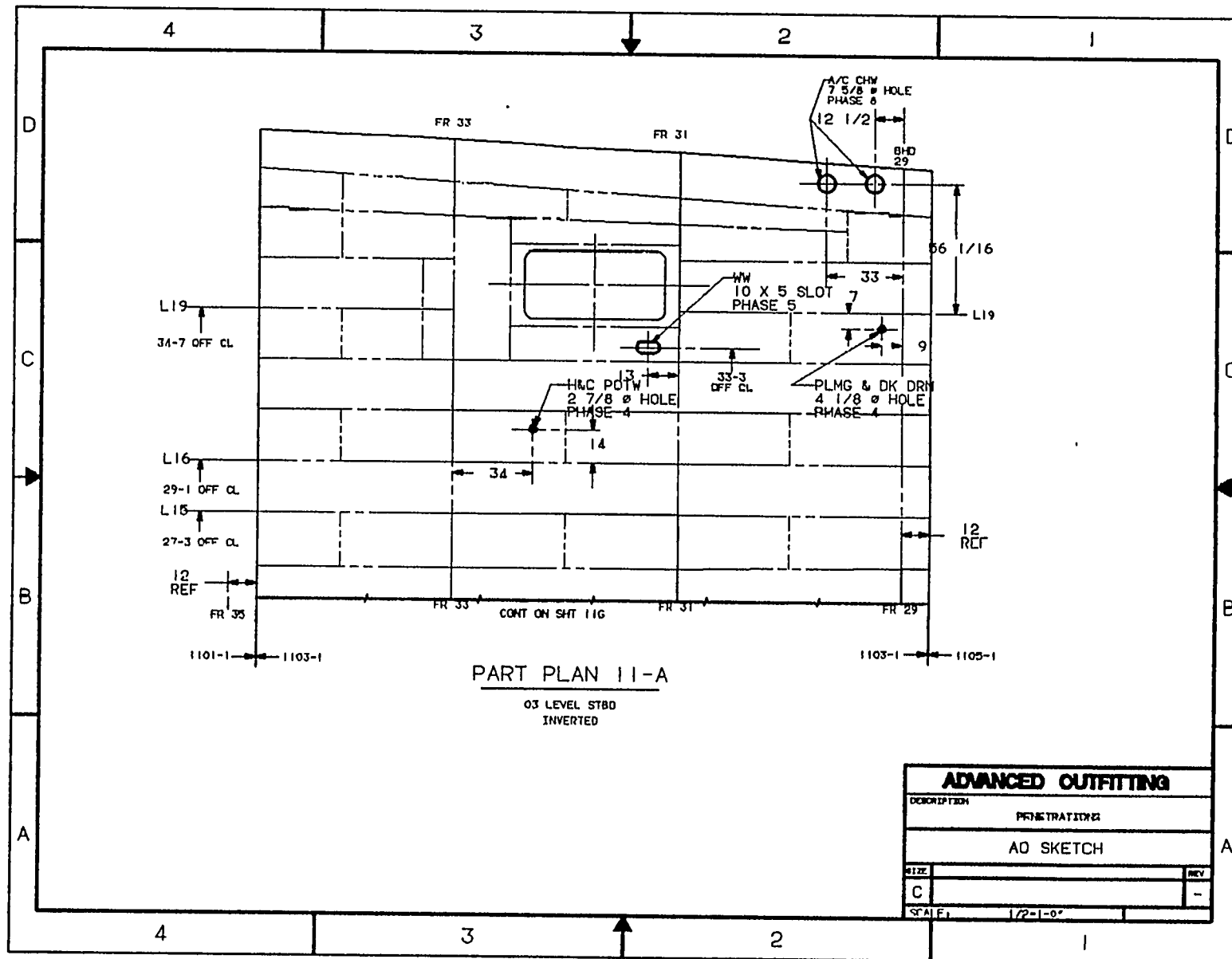
Utilizing the flow diagram as the guide, drawings must be produced to match the activity described in the flow diagram. The drawing should be oriented to the structure to which the outfitting items are being attached. If a deck panel is identified in the flow diagram as being outfitted in the inverted position then the drawing should be developed as the craftsman would see the job, i.e., inverted. The development of inverted drawing eliminates possible errors on the part of the craftsman trying to use a drawing which does not match the orientation of the piece he is trying to outfit. It should be noted that the use of "computer aided drawing" makes the development of inverted drawings very easy.

Drawings would be developed for each stage identified in the flow diagram and each drawing should match the orientation of the structure to which the outfitting items are being attached. This drawing approach requires a greater number of drawings than would be found with the system concept. Drawings are oriented to the outfitting of the unit as it is built. They also identify the material needed for each system within the unit. They also allow for portions of the system to be completed in accordance with the schedule as opposed to trying to complete a whole system drawing wherein certain portions would not be required for months later by production. In order to produce unit drawings the diagrams produced at the transition design phase would be overlaid on to a plan of the vessel showing unit breaks.



### Penetration Phase

Consideration should be given to the development of a penetration phase. The penetration phase should follow the identification of the panels which form each unit. The penetration phase consists of a series of drawings oriented to the position of the panel on the platen which identifies each hole in the panel, the system which passes through the hole and the phase on which is found the piping or ventilation for which the hole was cut. The penetration phase allows for all holes to be cut at one time prior to the erection of any panels.





### Curtain Plates

Curtain plates, used for the support of metal joiner bulkheads, should be installed early in the construction of the unit as it may be necessary to cut holes through the plates to support piping ventilation and cable installation. Installation of the curtain plates should be conducted in the downhand or inverted position to simplify the installation process. All dimensions should be given from longitudinal or transverse datums. Any details necessary for the installation of the curtain plates should be included in the drawings. All material needs should be identified to support the installation.



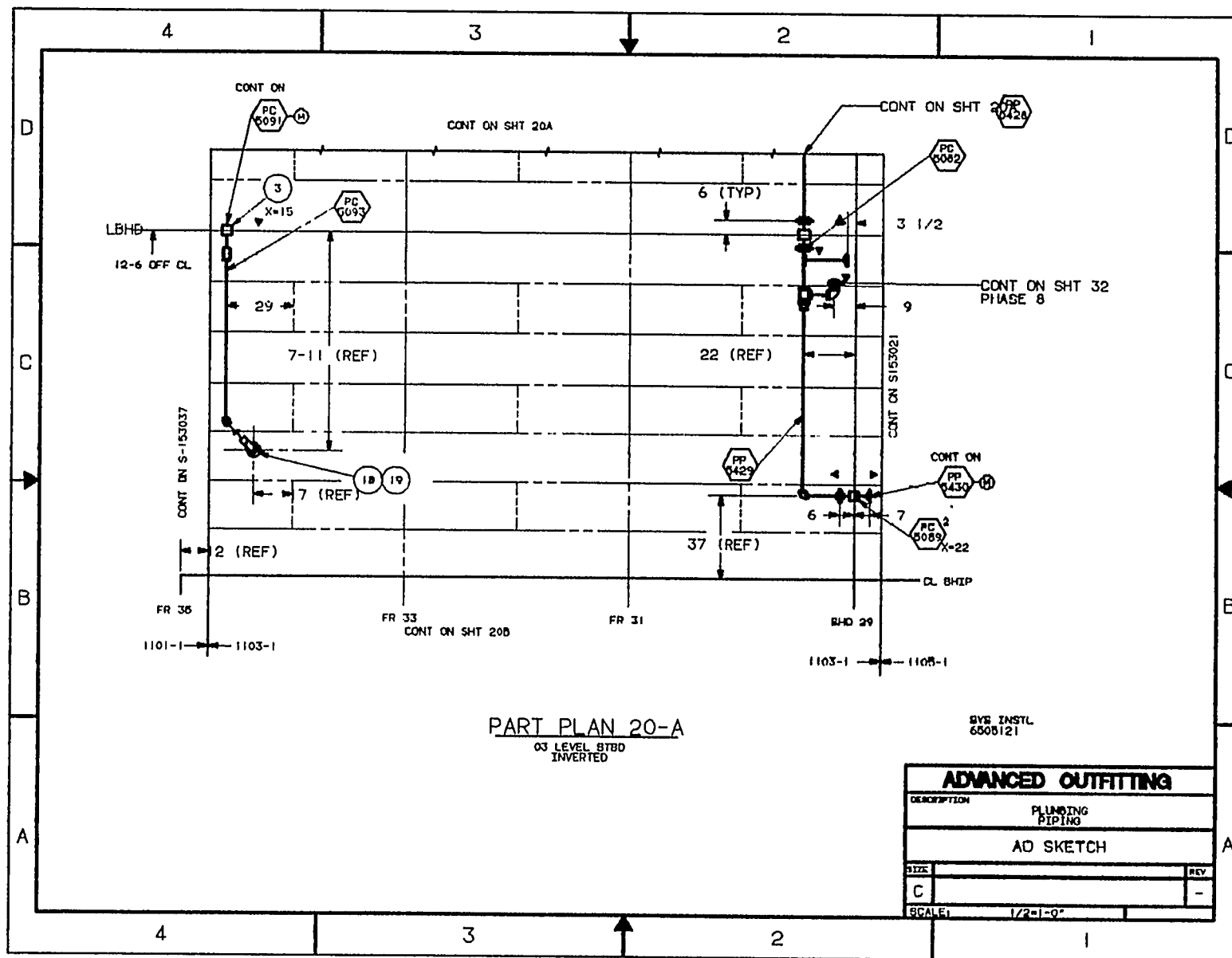
### HVAC Systems

Installation of the HVAC components is simplified through the use of fabricated assemblies. It also eliminates the need for staging and overhead welding. All HVAC fabricated assemblies should be identified and locating dimensions given from known structure. Most HVAC installations can be supported with plan views although sections and elevations should be developed for difficult or complex areas. All material and fabricated assemblies should be identified in the material list. The drawings and material lists should also identify make-up pieces. Make-up pieces are those pieces which are better installed late in the construction process. Make-up pieces are required when installation of other systems would be hindered by this component installation at this phase in the construction process or through the inability to support the component sufficiently to survive roll over of the subassembly. Make-up pieces are identified on the drawing as (M) and on the material list with an (M) following the assembly number.



### Piping Systems

Piping systems are among the most complex items to install due to the large amount of material such as valves, fittings, flanges, etc. It is possible to install not only fabricated assemblies during the steel assembly phase, but also field run piping. It is important to note that the designer must be aware of all components within the steel unit so that he may avoid interferences when developing the routes for field run piping. Piping usually requires the development of sections and elevations in addition to the plans, so that the fabricated assemblies can be properly located within the steelwork. Dimensions must be given off datums to the end of the fabricated piping assembly and the assembly break identified. Details pertaining to the orientation of valves or nozzles should be included along with directional flow arrows. As with other phases all material must be identified along with fabricated assemblies and make-up pieces.



### Material Lists

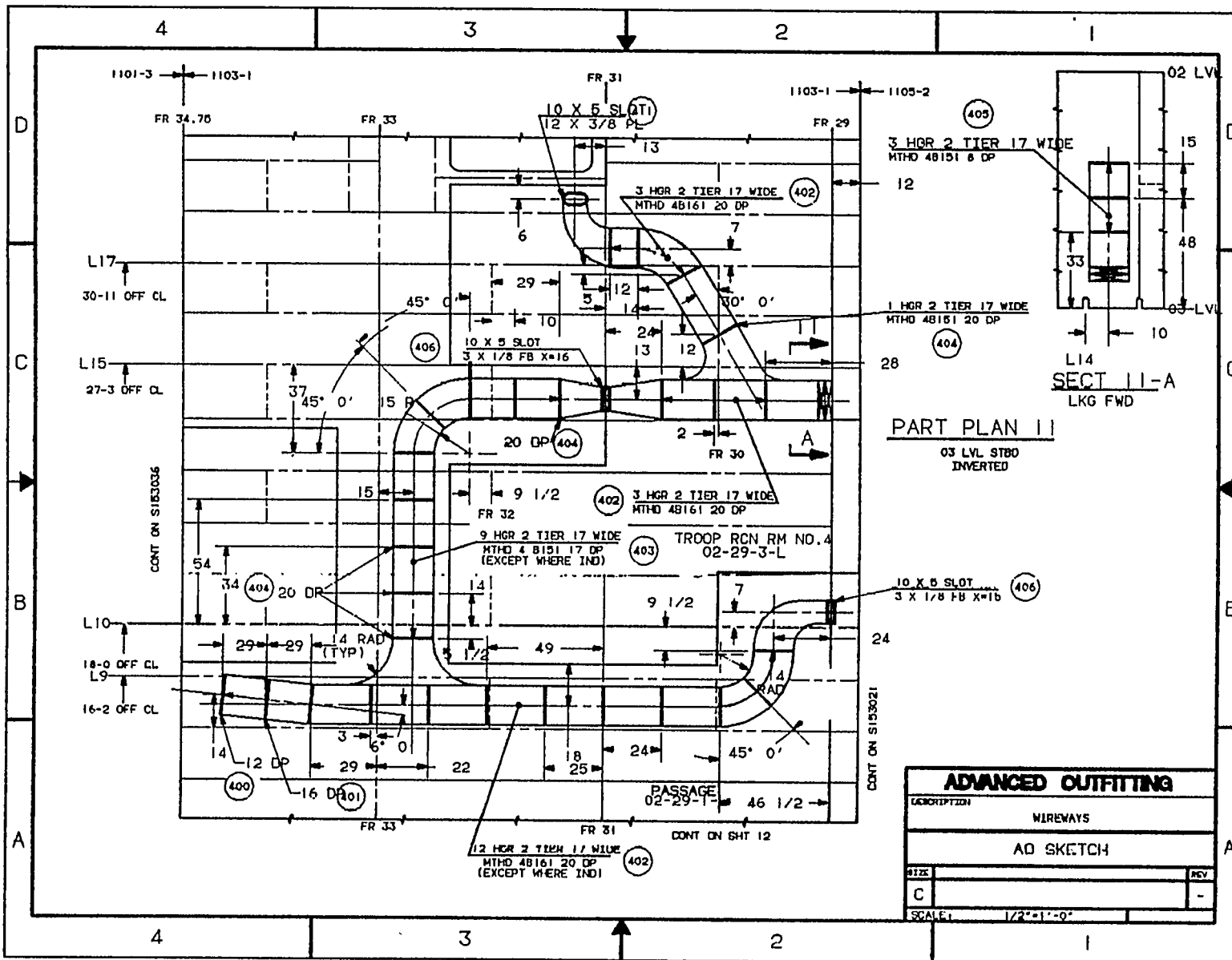
As each phase drawing is completed a material list should be developed which identifies all items installed in the phase. Since several systems can be installed within the same phase, attention should be given to the piece numbers assigned each piece as separate systems may contain the same piece number. It is important that the material remain within the drawing group. The development of material lists by phase allows for the material to be grouped as a "package" and sent directly to the work station.

[illegible]



### Wireway and Stud Runs

Wireways are installed following piping systems so as to avoid interferences with the piping systems, thus reducing rework. Each similar wireway hanger should be assigned a piece number. Assigning of piece numbers will allow for the shop fabrication of the hanger in sufficient quantities to support the installation activity. Location dimensions and spacing of the wireway hangers should be identified on the drawing. Lighting support brackets should be identified with piece numbers with dimensioning to only one leg required as the fixtures are of standard measurements. The use of "jig" or "fixture" can simplify light bracket installation. Junction boxes are located to support the length of cable normally supplied with lighting fixtures (10 feet). By locating the junction box, the route the cable will take is automatically determined. All other electrical drawings should be reviewed and the stud run routes established. It should be noted that, although the studs must be installed prior to the installation of cable, the cable run drawings should be developed first and the stud run drawings made from the cable drawings. Typical mounting details should be shown for various box, panels and equipment showing the bolt spacing which will allow for the mounting studs to be shot at the same time the stud runs for the cables are shot. All items of material should be shown in the material list along with estimated quantities.



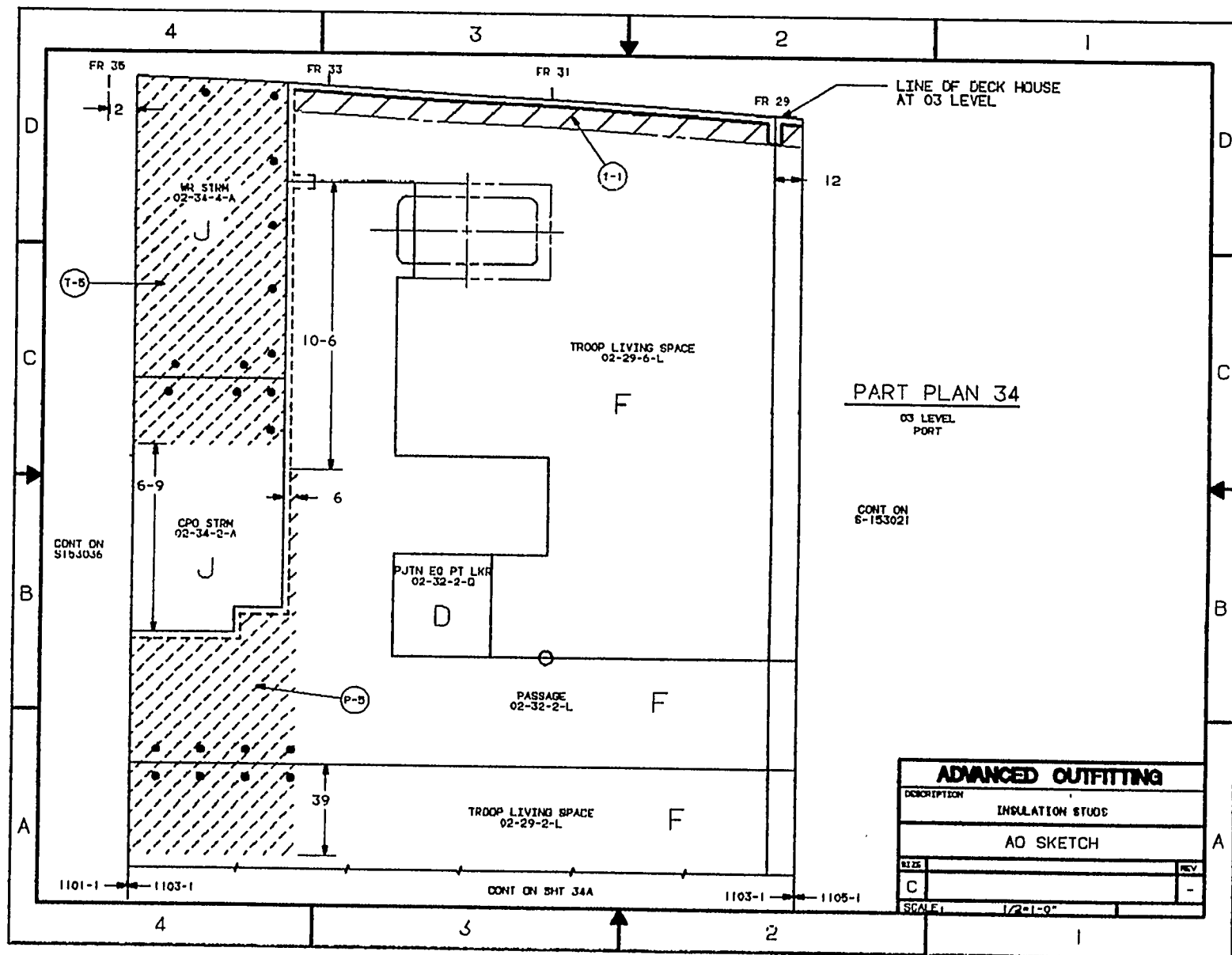
### Foundations and Equipment Installation

Foundation drawings do not provide the details of how the foundation is constructed as the foundation has previously been fabricated from its own assembly work station drawing. The foundation drawing provides the locating dimensions only. The module has been rolled over in accordance with the flow diagram and the drawings are now shipshape.

After the foundation has been installed, details of how the equipment is attached to the foundation are provided.

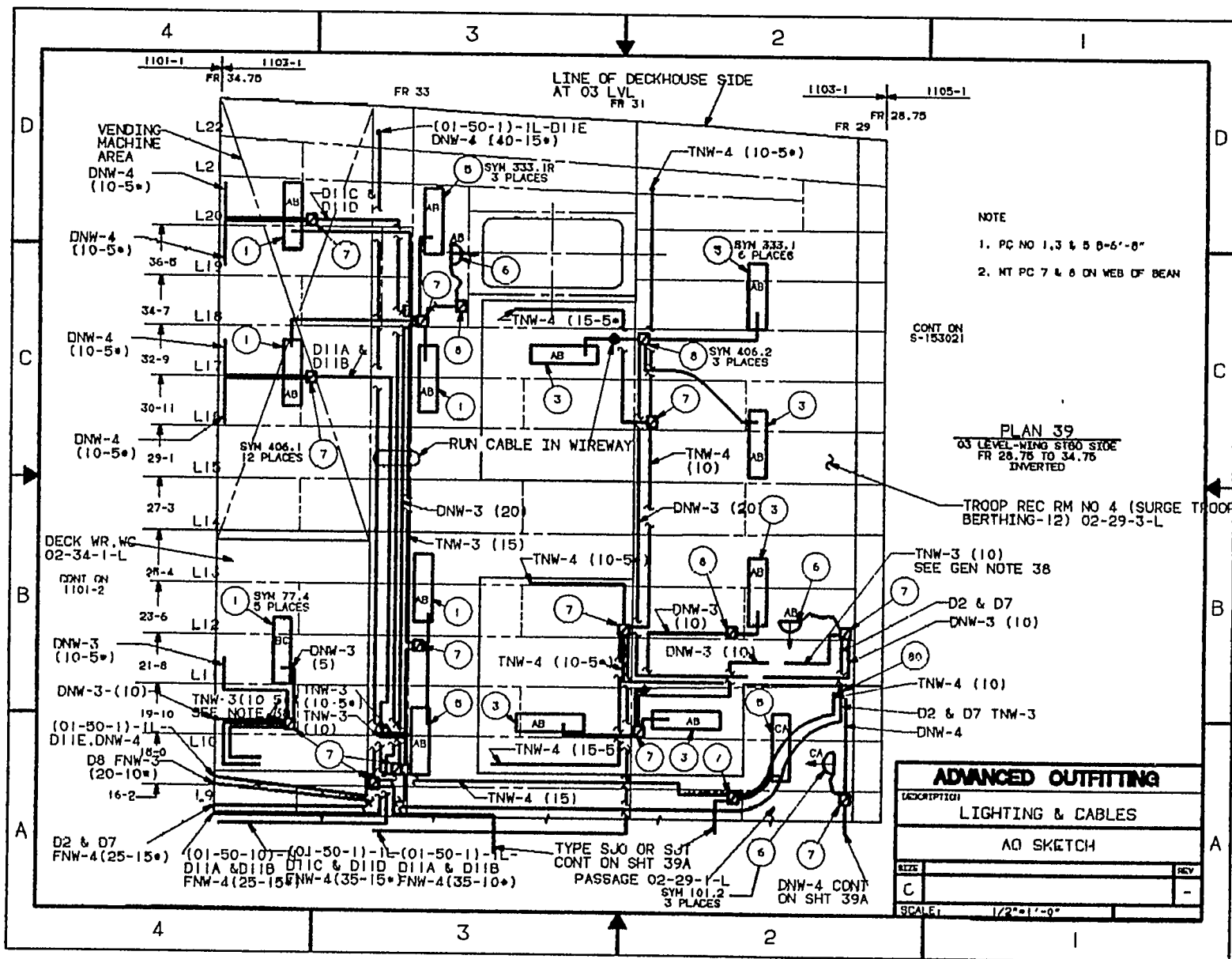
### Insulation Studs

Insulation studs are shot. at this time. A decision should be made prior to rollover as to the best time to shoot the studs so as to avoid injury to personnel. On this unit the studs were shot after roll over, although on others, studs were shot while the unit was still inverted. Shot blasting and painting follow the installation of the insulation studs.



### Cable and Electrical Equipment

The final phase is a follow-on to the electrical stud runs. All cables and electrical equipment including lights are installed at this time. The drawing identifies all circuits and cables within the unit and all cables which pass through the unit which would allow for the coiling of no more than 25 feet. All material has been identified and the number of various size cable hangers estimated. Since the studs were installed in an earlier phase installation of electrical equipment is simplified. It should be noted that the length of studs shot in the "stud run" phase have been calculated to accommodate the insulation. Upon completion of the cable and equipment installation phase, the outfitted unit is ready to be erected aboard ship.



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#### 2.2.6 FORMAT OF ENGINEERING INFORMATION

It is emphasized in this manual that the information provided to support a function must be tailored to the precise requirements of that function. Production information supplied to the designer must be in an easily usable form.

Similarly, the information provided to production must be tailored to the needs of a specific work station. This chapter describes the format of engineering information.

#### CROSS-REFERENCES

- 2.1.4 The Need for Formalization of Design Processes and Documentation
- 2.1.9 Communications between Design and Production
- 2.2.5 Detail Design
- 2.3 Ship Production
- 2.2.1 Conceptual Design
- 2.2.2 Contract Design
- 2.2.3 Functional Design

#### 2.2.6.1 Introduction

The approach to shipbuilding which is fundamental to this manual is based on work stations. Each work station is designed and resource to be able to produce a limited range of products. -In order to achieve the good levels of productivity, each work station must be supplied with correct packages of materials, and with all the necessary information relating to those packages.

The definition of work packages is a part of the planning and production engineering process. This begins with the build strategy and progresses into more detail along with the design. The detail design function takes the requirements which have been set, that is what work packages will be produced and when, and develops the supporting information.

The detail design process is outlined in Chapter 2.2.5. This chapter describes the format of the design output in more detail.

#### 2.2.6.2 Information Requirements

Modern shipbuilding practice is based on a well defined approach to the assembly and installation processes. These processes are best served by consistent and relevant production information. Conversely, if the production processes are not consistent and well defined, It is difficult and wasteful to try and develop specific production information.

Because production technology is dynamic, and changes as new methods and equipment become available, it is apparent that the information to be provided to production will change over time. This relies on a feedback system (Chapter 2.3.4).

It is important to consider why specific production information is necessary. Traditional drawings and other information formats are designed for one technical specialist to talk to another. Their function is to provide information about the complete vessel, or about a system within the vessel. The deck plan shows the continuity of the structure, adherence to regulations and correctness of connections. If the plan is presented to a production supervisor, he is only interested in one small part of that plan. He may also be interested in part of a bulkhead, which he must join to the deck but which is on a separate large drawing. Details may be hard to locate. If the deck is built upside down, orientation from a right side up plan may be difficult.

Although producing production specific information does require more detail design effort, it removes a lot of unnecessary work at the shop floor. Coloring plans, asking questions of design, making sketches, listing and searching for materials and simply puzzling are time consuming shop floor activities which should not be necessary.

In summary, information required for owners and regulatory bodies is different from that required for production. The format of that information should therefore be different. The design process can be regarded as developing two parallel and separate streams of information.

### 2.2.6.3 Functional Information

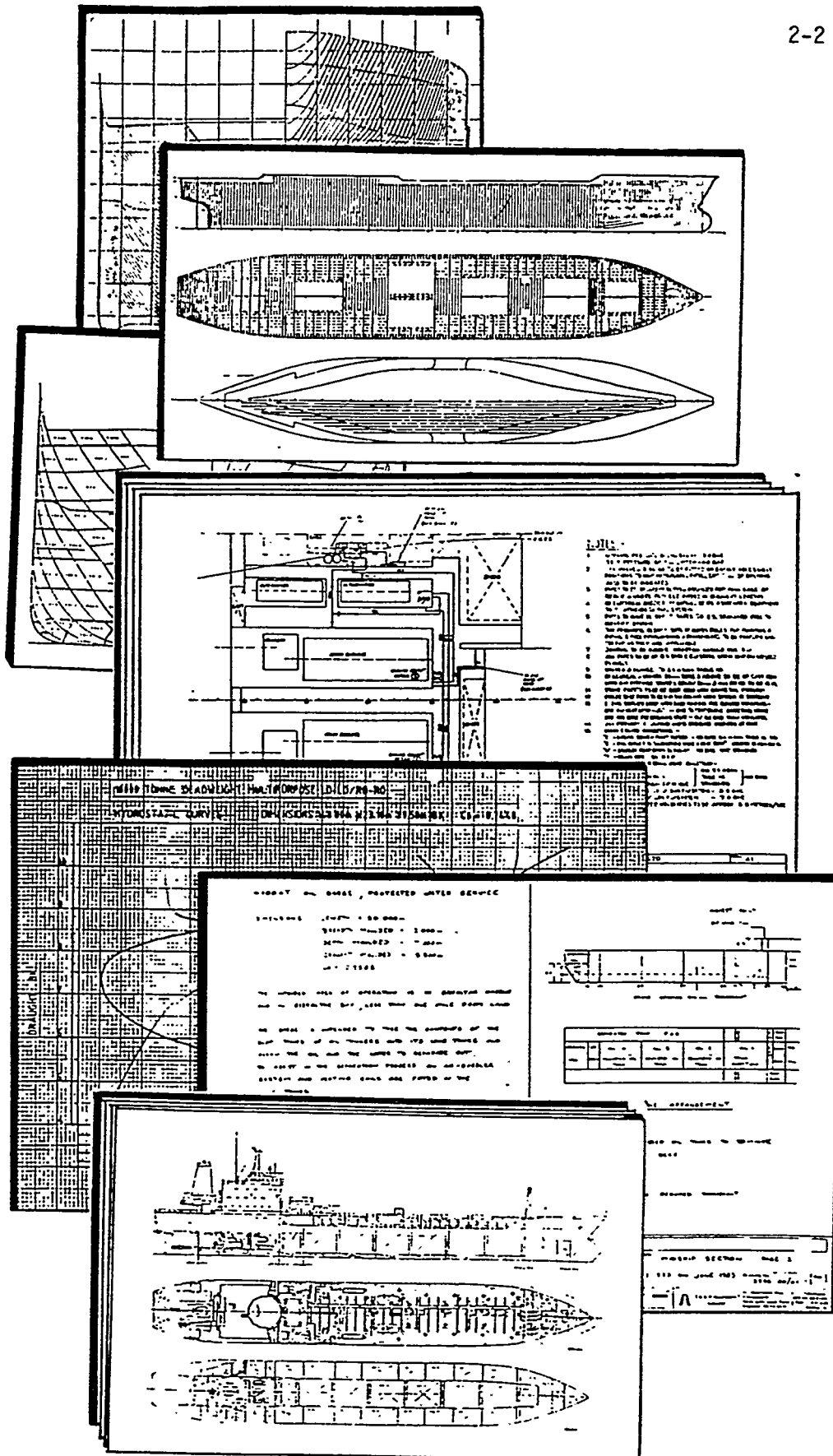
Functional information is covered by three of the design stages. These are:

- conceptual design
- contract design
- functional design

They lead from the initial concept of the vessel through to a full set of information to satisfy owner and all regulatory bodies of the vessel's ability to function as required.

These design stages could be totally independent of any production consideration, but this would undoubtedly lead to designs which are incompatible with production and therefore costly to build. The way in which production information should be used during design development is discussed in Chapters 2.2.1, 2.2.2 and 2.2.3.

When the information is produced solely for regulatory or other approval it is important to review its content, since no production data is required to be included. The information can be in any format provided it satisfies regulatory requirements.



#### 2.2.6.4 Production Information

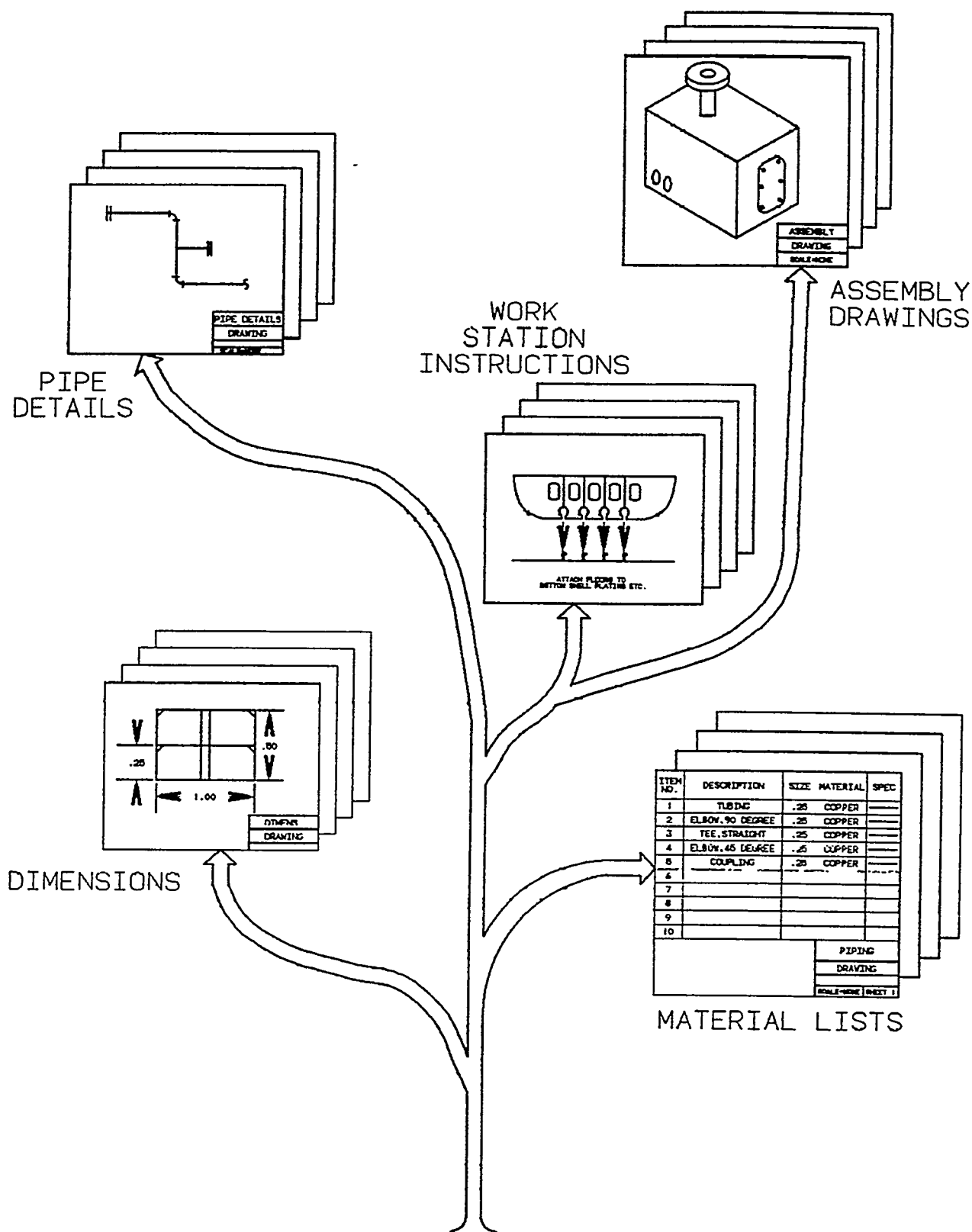
Production information should be developed in parallel with functional information. At each stage of the design there is a corresponding set of production outputs. The main outputs are collected into document form and issued to appropriate functions. The main documents and corresponding design stages are:

Shipbuilding Policy (1.2.2)	-	Conceptual Design
Preliminary Build Strategy (1.2.4)	-	Contract Design
Contract Build Strategy (1.2.4)	-	Functional Design

Integration between design and production takes place principally at the transition design stage. Thereafter, the detail design stage is primarily concerned with the development of production information. The development of detailed arrangements is left until late in the overall design process. The detail design is carried out in terms of the planning units, so that it can be divided into small packages and carried out to a schedule geared closely to production requirements.

# DETAIL DESIGN OUTPUTS

2-2 /607



#### 2.2.6.5 Process Analysis Information

Process analysis is carried out by the production engineering function. The purpose of process analysis is to define the way in which planning units will be produced, as a basis for the detail design stage. Although process analysis is part of the transition design process, it can begin to influence a design at an earlier stage through the incorporation of "standard" process analysis information in the shipbuilding policy. This information can be used to give a preliminary analysis for the build strategy, incorporating any variations in "standards" to suit the particular vessel. A preliminary estimate of work area throughput can thus be generated.

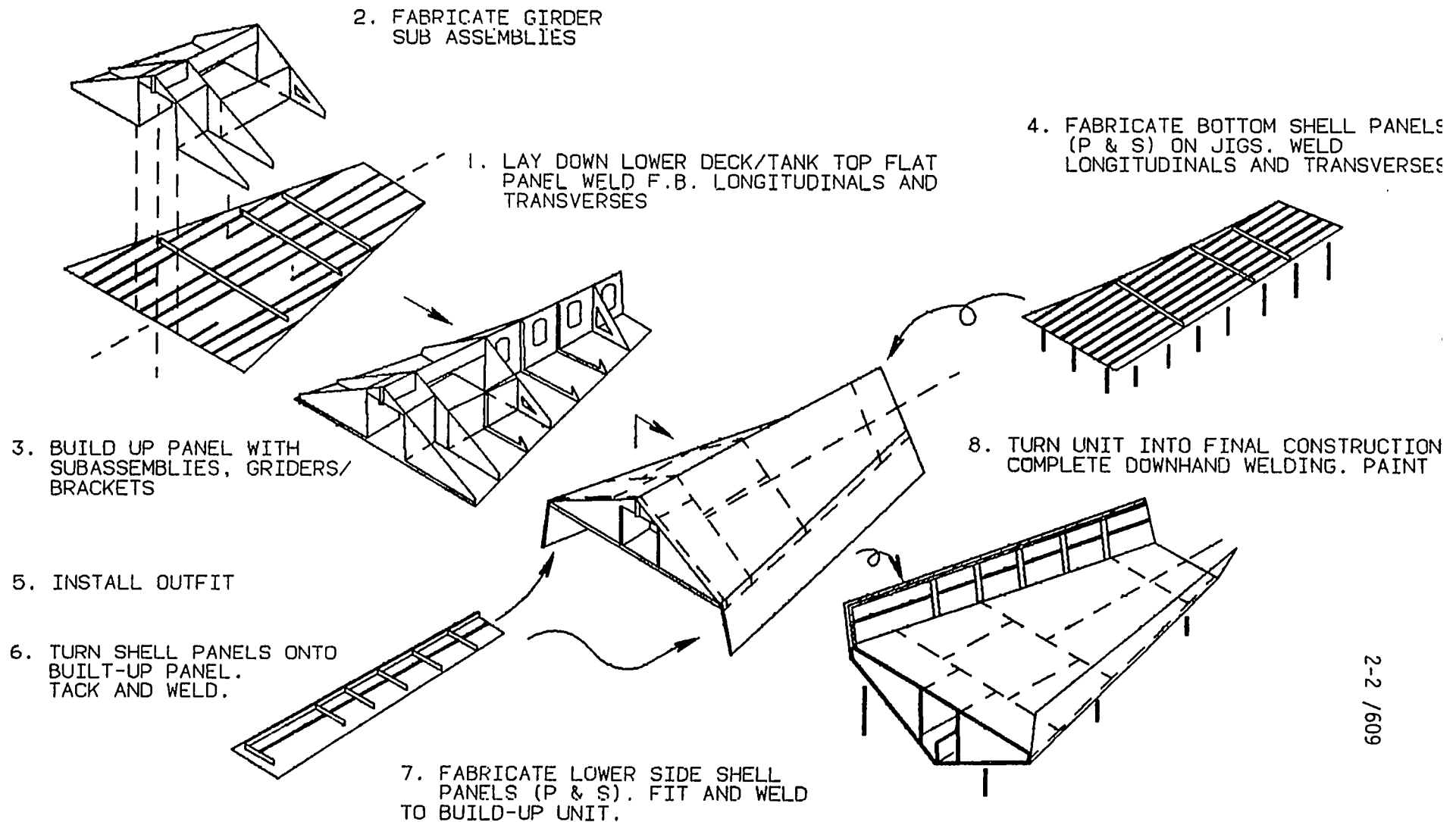
The analysis also provides the design function with an initial list of products, each of which will require its own set of production information.

The precise format of information will vary, but the main features which are necessary are:

- A sketch of the planning unit.
- A flow diagram showing its assembly sequence.
- A code number for each assembly.
- The work station associated with each assembly.
- A preliminary estimate of work content.

A listing of all assemblies in a register is a useful way of ensuring nothing is overlooked. The assembly register is the basis of a plan list for detail design.



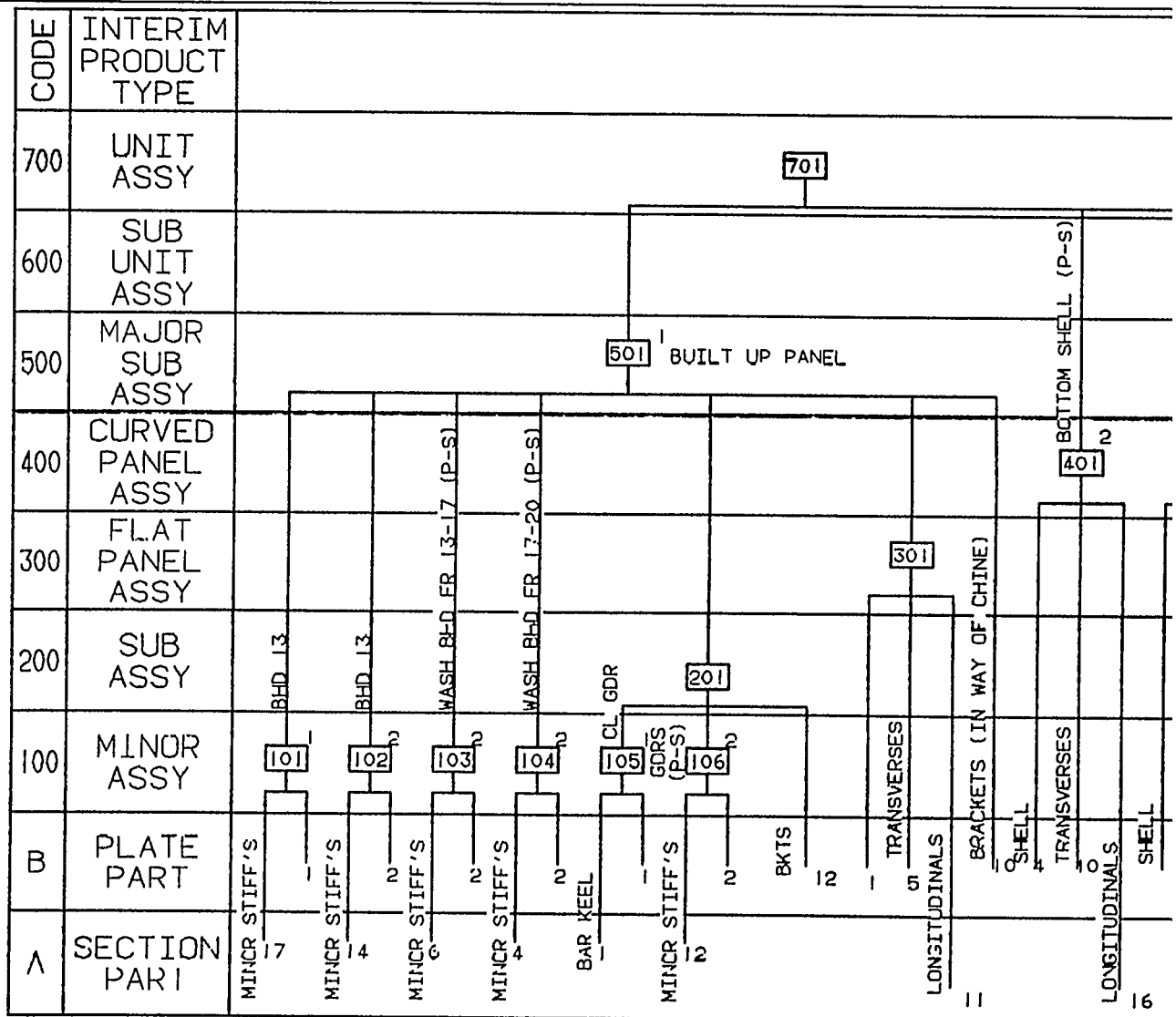


After contract signing, a more detailed analysis is carried out. This covers all the assemblies in the vessel, down to piece parts. The main features of the information provided are:

- A sketch of the assembly.
- A flow diagram showing sequence of assembly.
- A code number applied to each subassembly.
- Work stations associated with each subassembly.
- Estimate of work content for each subassembly.

A complete register of all assemblies and subassemblies can be created which defines all the production information which will be required. In conjunction with tactical planning, showing when information is required, the register is the basis of the detailed design work program.

## UNIT NO. 103-DESCRIPT:



#### 2.2.6.6 Work Station Drawing

The assembly analysis will have defined a particular interim product, for which production information is needed. The product will be associated with a work station, for which facility and process information should be available (Chapters 2.3.2 and 2.3.3). Contract and transition design information is available from which to develop the details of the product.

From this information, work station drawings are created. The format, of the drawing can vary, but a number of essential features can be identified. For ease of handling on the shop floor, paper sizes up to 11 x 17 should be used. These can be conveniently bound where several sheets go together, and are easy to store. In the case where several crafts are involved, more than one sheet may be needed.

A drawing is required for each work package, at each work station, for each stage and assembly. The drawings will contain only the information needed for the appropriate work package. The drawings contain all the information needed to complete the work package which they relate.

The main features of the format illustrated are:

Dimensional accuracy. Critical dimensions for interfacing with later activities are identified. Dimensions relate to datum lines. Tolerances which are acceptable are listed. Areas where excess material is required or where items should be left unattached are identified.

Isometric drawing of the assembly. This shows the assembly as it is oriented on the shop floor. The stage of completion at the work station is shown. Dimensions, from datum lines which are relevant to the subject of the drawings are shown. The various parts and subassemblies are coded.

Production methods. Any particular requirements, for example, fairing or welding methods, are indicated.



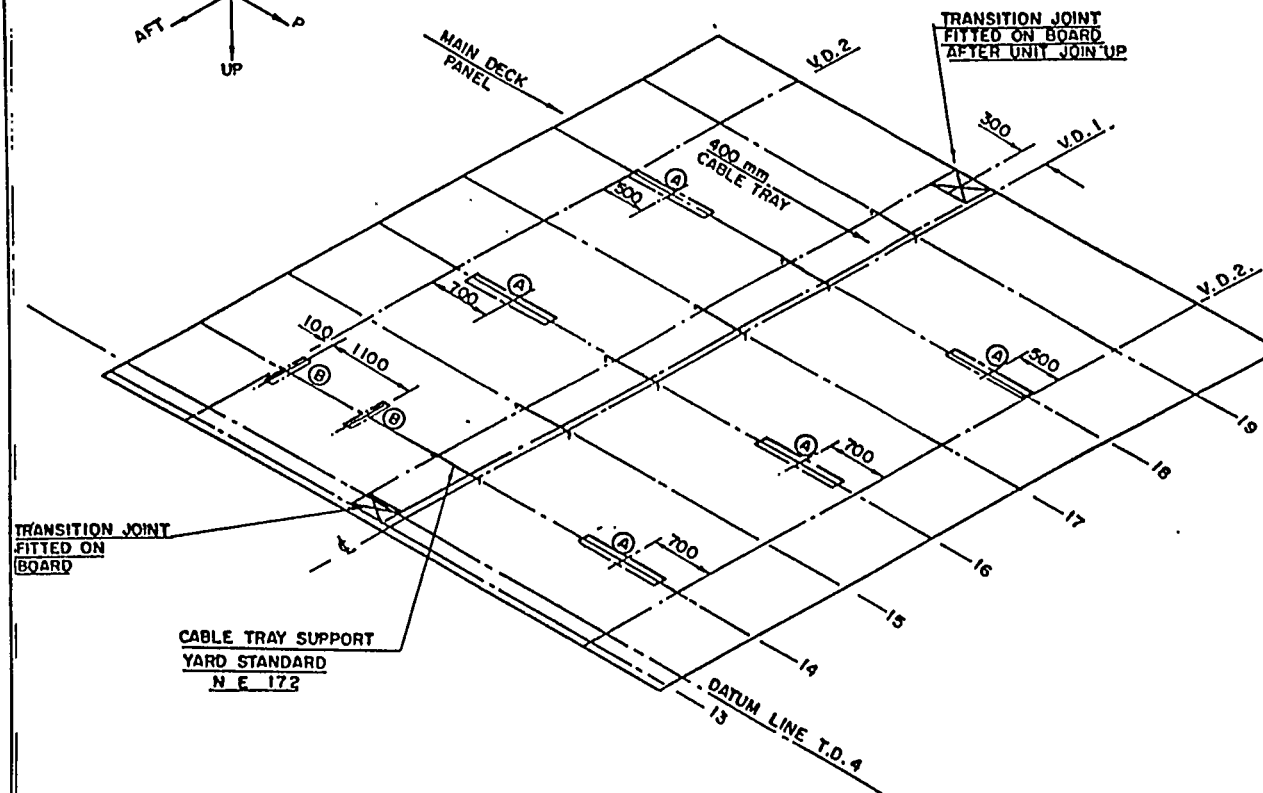
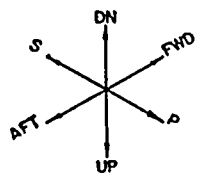
Work Content. For each item the parameters used and actual work content are shown.

Material list. A complete list of parts and assemblies needed to complete the work package is given. Codes and quantities are shown.

Administrative information. The assembly number, planning unit number and ship number are quoted. The work station code at which the work will be carried out is given and destination of the finished assembly. The number number of assemblies to be produced and the weight are also given. Finally, the drawing date, page number, revision number and draftsman's initials are included.

In addition to the above, the planned start and finish date are required. These will generally be given on a separate schedule for each work station. The schedule will give all work packages for the work station.

In some cases an arrangement drawing showing the orientation of the assembly in the work station may be needed. This can be shown separately on the work station format which is part of the input to detail design. In most cases, the orientation can be indicated by reference to the orientation at the ship.



## WORKSTATION DRAWING

DRAWING N°:

DESCRIPTION:-

ELECTRICAL CABLE TRAY & LIGHT FITTING  
SUPPORT UNIT 203 (DECKHEAD)  
(FRS 13-19)

SHIP N°:

WORKSTATION:-

DESTINATION:-

### PARTS LIST

PART N°	N°OFF	DESCRIPTION
E 172	6	CABLE TRAY SUPPORT
E 098	5	LIGHT SUPPORT (A)
E 091	2	" " (B)
E 006	1	400mm CABLE TRAY (7metres)

DRAWN BY:-

DATE .....

### REVISIONS

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### 2.2.7 THE IMPACT OF CAD/CAM

This chapter has been included in the manual to illustrate the desirability of utilizing a CAD/CAM system to assist in the development and formatting of engineering information. CAD/CAM can be the ideal tool to supply the increased engineering output needed for design production integration while still reducing engineering manhours.

#### CROSS-REFERENCES

- 2.2.1 Conceptual Design
- 2.2.2 Contract Design
- 2.2.3 Functional Design
- 2.2.4 Transition Design
- 2.2.5 Detail Design
- 2.2.6 Format of Engineering Information

### 2.2.7.1 Introduction

The design for production techniques described in this manual are readily adaptable to CAD/CAM. It is, in fact, CAD/CAM that makes practical the Presentation of design data in the multiple formats required by this approach. The following sections will discuss specific benefits of CAD/CAM, provide a generalized model for CAD/CAM cost justification, and briefly discuss the ultimate CAD/CAM benefit, Computer Integration Manufacturing (CIM).

### 2.2.7.2 The Benefits of CAD/CAM

The following paragraphs discuss the benefits of CAD/CAM in the design/production process. The figure (page 2-2/703) is provided to illustrate the relationship between inherent system characteristics, interim benefits and the ultimate benefits to the shipyard.

#### Drafting Speed

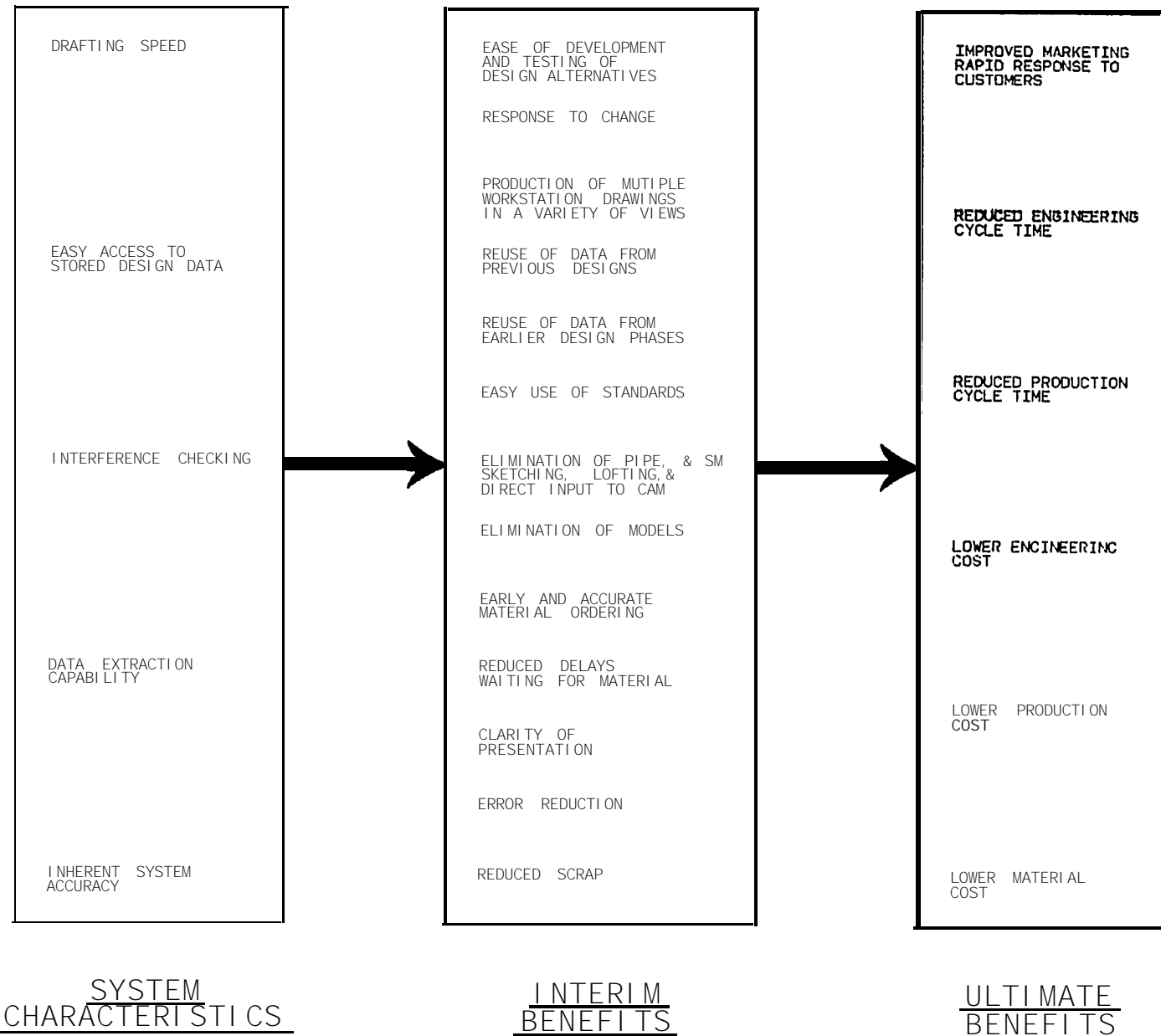
The most obvious advantage of CAD/CAM is a simple increase in drawing speed. Although this will ultimately represent only a small portion of the overall savings, it is the most visible. The ability to quickly insert entities and copy and mirror existing input can contribute significantly to the designers productivity.

#### Reuse of Data Generated at Earlier Design Phases

More important than the simple increase in speed, however, is the creation of a single or multiple interconnected design database. As the design develops through progressive stages, the level of detail increases and the focus of attention shifts from systems to areas and from the whole vessel to parts of the vessel. In lieu of the normal process of tracing and copying previous work at each new stage, the database allows reuse of previously generated information.

Entire steps in the design process will ultimately be eliminated including pipe sketching, sheetmetal sketching, lofting and the production of NC data for piece part manufacturing and steel cutting. Design effort will be reduced as preliminary models are used in engineering analysis including flow analysis, naval architecture and finite element analysis. Data stored in the system will aid in the production of technical manuals and test procedures.

# THE BENEFITS OF CAD/CAM



Information generated in conceptual design and all later phases is continuously updated and used for the life of the contract. This simultaneously increases efficiency and reduces the possibility of errors.

### Efficiency Production of Large Numbers of Drawings

A major objective of design for production is to provide the worker with a drawing that shows only the information needed for the task at hand. Since much less data appears on each drawing, many more drawings must be generated. CAD systems provide powerful tools to achieve this goal. Through proper selection of parts, figures, and layers, drawings may be produced of any desired portion of the database without redraws. Since all information must be entered in very specific ways, proper planning is a critical issue. Clear guidelines must be established and enforced if the information is to be extracted in a simple and orderly fashion.

### Clarity of Presentation

Once the model of an area has been produced, working drawings may be produced using any desired views. Units may be shown in the orientation corresponding to the actual building position. Isometrics may be produced almost as easily as any other view. With solid modeling, shaded pictorial views are available for illustrative purposes. In many systems, portions of the foreground may be eliminated producing windows through which hidden structure may be seen.

Inherent to the CAD system, is the ability to obtain dimensions across any plane with reference to any datum. If the designer is properly educated as to what check dimensions and fitting up data is required on the shop floor, this information can easily be placed directly on the drawings and significant hours can be saved in production.

### Standards

The establishment of standards is recognized as a key to designing for efficient production. Standards reduce the diversity of parts, increasing the proportion of pieces amenable to production line and family piece part manufacturing. Since standards are done only once and then reused, it is economically feasible to invest the production and industrial engineering effort required to produce the most efficient design. Once developed, standards represent blocks of error free engineering and thereby reduce errors.

CAD contributes to the ease with which standards can be created and utilized. Libraries of standard piece parts can be placed in the database and accessed and inserted almost simultaneously. For ease of manufacturing, families of standard parts can be created which vary only in a few critical dimensions.

#### Unitization of Existing Designs

CAD/CAM makes the use of portions of previous designs very convenient. Since these portions of previous designs presumably represent blocks of proven, error free design, their use not only increases productivity, but also reduces production and engineering rework.

#### Ease of Development and Testing of Design Alternatives

The CAD system allows consideration of a greater number of design alternatives because of the system speed and the ease with which the input may be changed once the model has been built. By considering more alternatives the probability of achieving a time and cost effective design is increased. This capability is useful both in detail design and in conceptual and contract design where fast response to customers needs may make the difference in obtaining a contract.

#### Reduction of Errors

The use of CAD/CAM also contributes to a reduction in errors. A portion of this reduction is a result of the inherent drawing and dimensioning features of the system. Probably more important is the elimination of copy errors resulting as information is passed from one design phase or discipline to another. The continuous updating of the database can also eliminate errors that occur when an area of the vessel is modified after other disciplines have utilized the previous information.

#### Response to Change

The existence of the database also greatly increases the designers ability to respond to change. Previous models of the affected area may be called up and modified without the necessity of complete redraws.

With proper system integration, the speed with which changes may be transmitted to production is also dramatically increased.

### Increased Productivity From Scarce Technical Resources

In the present cyclical shipbuilding market, most shipyards experience difficulty maintaining or building an adequate staff of properly qualified technical personnel. This problem is eased by increasing the productivity of available designers.

### Interference Checking

The existence Of a composite model reduces the difficulty of checking for interference between parts of different systems and between parts and structure. Many systems provide automatic mathematical interference checking. Reduction in interference reduces both engineering and production rework.

### Ultimately Eliminates the Need for Models

In the long term, CAD generated 3D models will eliminate or greatly reduce the need for physical models.

### Earlier and More Accurate Material Ordering

The successful integration of CAD with material control systems will lead to earlier and more accurate ordering of parts. CAD will ultimately feed data directly into the material control system resulting in reduced build cycle times and reduction in delays incurred waiting for material. More accurate identification will also result in a reduction in scrap material.

### 2.2.7.3 The Ultimate Impact - CIM

In coming years, computer based systems will revolutionize the design and manufacturing process. This revolution will be the result of full integration of CAD, CAM, CAE, Material Control, Planning, Production Control and other computer based design, manufacturing and management information systems. This integration will result in what is being referred to as Computer Integration Manufacturing (CIM). Although we are all impressed with the design and manufacturing capabilities of the present day hardware and software, the real productivity gains will be achieved only when this complete level of integration is achieved.

In order to achieve this level of integration, CAD/CAM cannot be implemented alone, but must be thought of as only one facet of an overall shipyard integration plan. CAD/CAM can however serve as a synergistic force in the task of weaving the shipyard computer based management information systems into an integrated, powerful tool for increasing productivity.

The building of "Bridges" between information systems must be given a high priority to avoid the development of islands of automation unable to communicate with each other. The advantages of basing all operations on a single database cannot be over stressed.

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VOLUME 2

DESIGN/PRODUCTION INTEGRATION

PART 3

SHIP PRODUCTION

2.3 SHIP PRODUCTION

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### 2.3.1 MODERN SHIP PRODUCTION TECHNOLOGY

This part of the manual describes ship production, as it relates to the design function. In this chapter, a description of modern production processes is given. It is included to provide those persons involved in the design process who have no direct production experience with a resume of the methods and facilities they would expect to see in an up-to-date shipyard. All aspects of production are discussed, but the intention is to draw attention to relevant aspects of production rather than provide a comprehensive description.

Chapter 2.1.1 discusses the influence that design can have on vessel cost. The influence curve illustrates the fact that the opportunity to develop a producible design exists at the earliest stage. As the design develops, more design variables become fixed, and the opportunities to incorporate producibility are reduced. To take advantage of the early opportunities, the designer must understand the production processes.

### CROSS-REFERENCES

- 2.1.6 Impact of Facilities on Design
- 2.3.2 Guidelines for Facility Capability Documentation
- 2.3.3 Guidelines for Production Process and Method Information Documentation

### 2.3.1.1 Steelwork Production

The production of steelwork for a vessel normally gives rise to the largest single item of cost in terms of manhours. Steelwork facilities are usually the largest item of capital investment.

Efficient use of the facilities which are available, by matching the design to facility capability is essential to creating a low cost product. Chapter 2.3.2 illustrates how the necessary facility capability data can be presented to the designer.

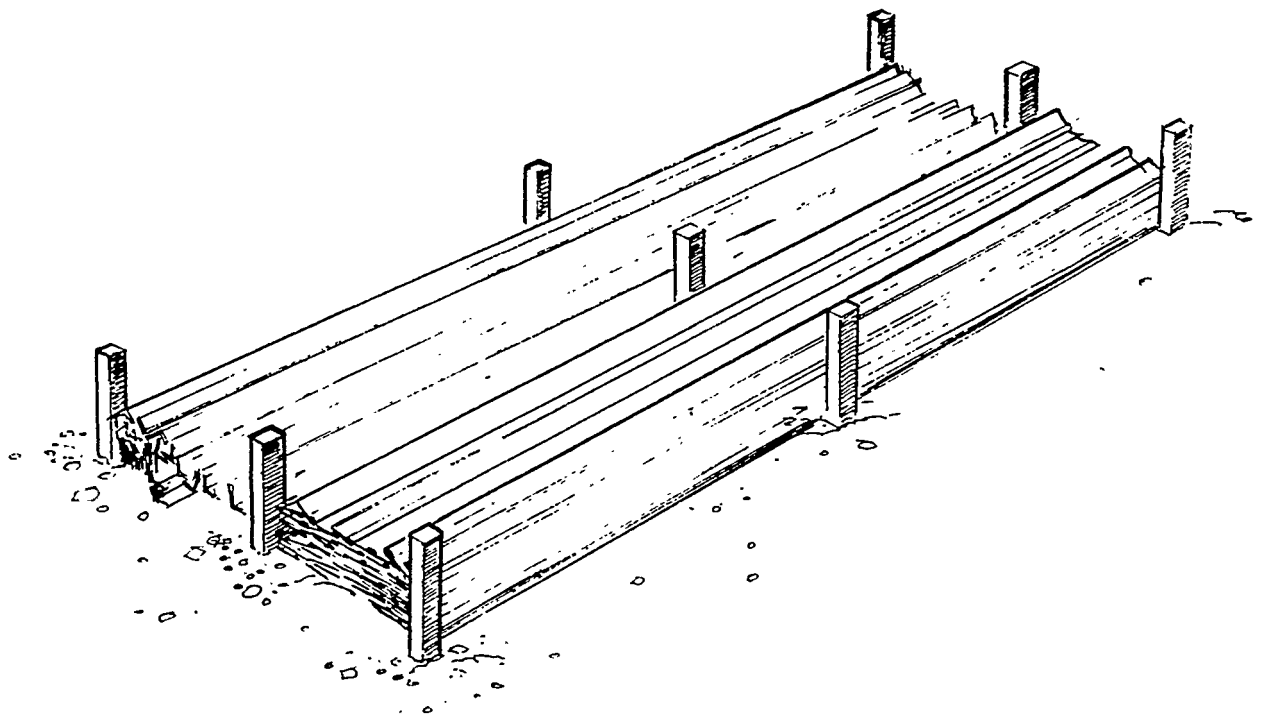
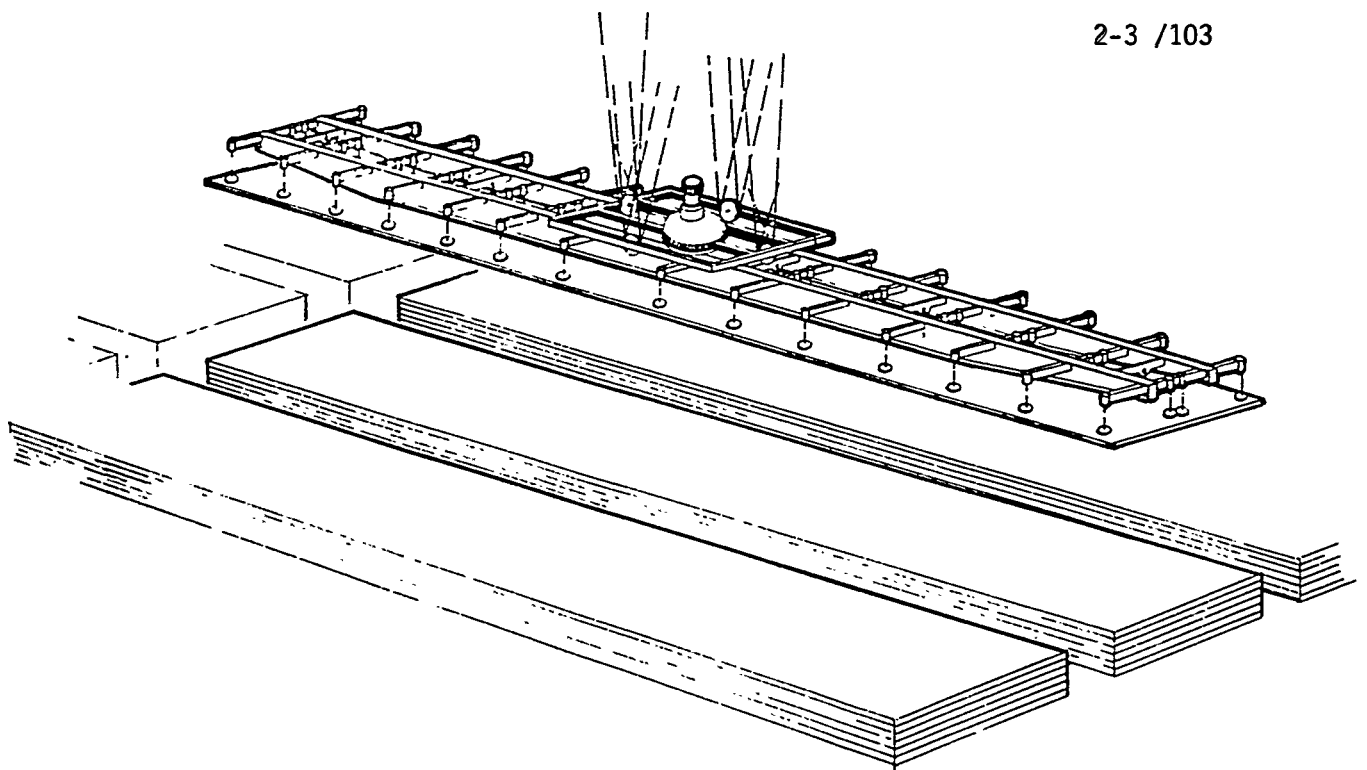
### 2.3.1.2 Stockyard

The main function of the stockyard is to act as a buffer to smooth out the variations in steel supply from the mill and demand from production. Piles of plates are stored flat, directly on the ground. To keep handling and sorting to a minimum when the plate is withdrawn from the stockyard, the plates are stored by ship, structural group and by unit or group of units. Handling of plates is by a magnet beam attached to a crane. All sizes of plate in the flat position can be picked up and put down without assistance from the ground. The required manning in the stockyard is therefore small.

Where the shipyard has standardized on a limited number of plate sizes and thicknesses, plates may be stored by size, considerably reducing storage and handling requirements and simplifying sorting operations.

Shapes are stored between vertical posts and are handled by a magnet beam or by slings attached to the beam and may be stored by unit or by type and size if standards are used.

The cost of equipment and operations in the stockyard can be considerably reduced by standardizing material sizes. The area required for storage and the number of sorting operations can be reduced.



STOCKYARD

### 2.3.1.3 Surface Treatment

Treatment is the first steel process, the key parameters are the width and weight of plates for which the treatment facility has been designed. Clearly there is no need to optimize on the plate weight, but the ability of the equipment to handle up to a maximum defined width should be noted - this width should be consistent with optimum material sizes in other areas.

Steel plates as received from the manufacturer generally have residual stresses from the rolling process and from cooling. These may cause distortion when the plate is cut and the stresses become out of balance. Distortion of components causes fairing problems during the assembly stage. A plate straightening roll incorporated in a treatment line is used to relieve the residual stresses by a process of plastic deformation. The rolling also ensures that plates are flat before cutting, and can assist the shotblasting process by breaking up mill scale on the plates.

Rolling is followed by shotblasting to remove scale which could otherwise interfere with subsequent cutting, marking and welding operations.

Painting with primer creates a barrier against corrosion during fabrication and during the time prior to final cleaning and painting and gives a basis for the final surface coatings applied after assembly.

For the quantities of steel required in shipbuilding, the most effective method to shotblast and paint steel plate and shapes in a shipyard is by use of an automatic treatment line. This reduces handling costs and gives opportunities to maintain levels of quality that cannot be matched by any manual system.

An automatic treatment line can handle plates or shapes and in some cases both. Shapes are processed in batches. The equipment consists of an infeed conveyor, a drying plant, shotblast machine, paint priming plant, drying tunnel and outfeed conveyor. The line is loaded and unloaded by magnet crane.

#### 2.3.1.4 Plate Cutting

Plate lengths and widths are critical and cutting machine beds will have been designed around a certain plate batch. The number of plates that can be cut-at any one time will clearly be a function of the number of cutting heads and the dimensions of the standard optimum plate size- around which all steel facilities have been designed. The designer needs to be aware of optimum plate sizes for cutting.

The number of manhours required to assemble any given unit is very dependent upon the dimensional accuracy of the components making up that unit. For this reason, the accuracy of the plate cutting plant is extremely important and parts should be cut to the smallest tolerance consistent with facilities. This accuracy is only achieved continuously with numerical control burning machines. The families of parts to be cut and the machines most commonly used are:

Rectangular plates with/without : edge preparation	Flame planing machine with torches for edge preparation.
Internal structure; webs, floors, : girders, etc	2 axis NC oxy/fuel or plasma machine.
Curved shell plates generally : with edge preparation	3 axis NC oxy/fuel with torches for edge preparation.

All the machines have multiple heads, normally four when cutting two plates at a time, and also NC punch or powder marking (zinc or aluminum) can be incorporated, giving very accurate lines and datums for future assembly operations. Oxy-gas burning machines or plasma machines are used for plate cutting; oxy-gas is the traditional process while plasma **is faster (eight times for ½" plate)**, but cutting must be done underwater in order to cut down on the amount of fumes and noise given off during the cutting process.

The heat input while plates are being cut can also cause distortion which can be minimized by careful nesting of the parts, by leaving bridges between the parts and also by careful choice of cutting sequence. Because plasma cutting is done underwater, heating effects are reduced, and distortion is less than with oxy-gas cutting, particularly for thin plate.



### 2.3.1.5 Shape Cutting

The shape cutting area or machine should be geared to an optimum shape length and scantling. The optimum length will be related to plate sizes, as the two will come together to form an optimum size and weight flat or curved panel. The designer therefore needs to be aware of optimum and maximum shape lengths and weights.

Shipyards are employing an increasing amount of automatic and mechanized shape cutting machines in conjunction with magnet cranes and special purpose conveying and handling equipment. The older, traditional shipyards predominantly use hand marking and hand cutting methods. Shape cutting is a less complex operation than plate cutting. There are three major categories, each requiring different cutting techniques.

Shapes which are to be attached to flat plate panels require accurate length and end weld preparation. The possibility exists of using hand or semi-automatic cutting. However, for the production of accurate panel blocks, which will permit rapid fairing and welding during assembly, automatic length measuring devices are used. Accuracy of weld preparation will be critical for mechanized joining techniques.

Shorter shapes for subassemblies, which are not normally welded at both ends and therefore do not need to be prepared to a great accuracy, may be cut by hand torch or portable, semi-automatic machine. There is also a possibility of using circular cold saws to cut this group of shapes in batches. Bent frames will also be required to be cut. They fit into the second category, but because of their variety of shapes, hand or semi-automatic tractor cutting is generally used.

Minor shapes to be cut to length and possibly sniped (cut obliquely), are either prepared by a universal steelworking machine or are hand marked and cut.

#### 2.3.1.6 Plate Forming

Plate forming equipment should be sized in line with treatment and cutting facilities in terms of the size and weight of plate that can be handled. It is sometimes the case in an existing facility that the capacity of the forming equipment is less than that for the cutting equipment. The designer therefore needs to be aware of the maxima for the forming equipment itself rather than assuming equipment sizes from cutting machines or treatment facilities.

There are two main plate forming activities:

- The forming of the curved shell plates of the ship.
- The forming of corrugations for bulkheads and superstructures.

In addition to the above, there are flanging requirements for brackets and flanging and rolling requirements for masts, tank hatches and other outfit steel items. Most shipyards employ a combination of the following items of equipment:

shell roll,  
combined shell roll and flanging machine,  
flanging press,  
portal press,  
gap press,  
press brake,  
small roll.

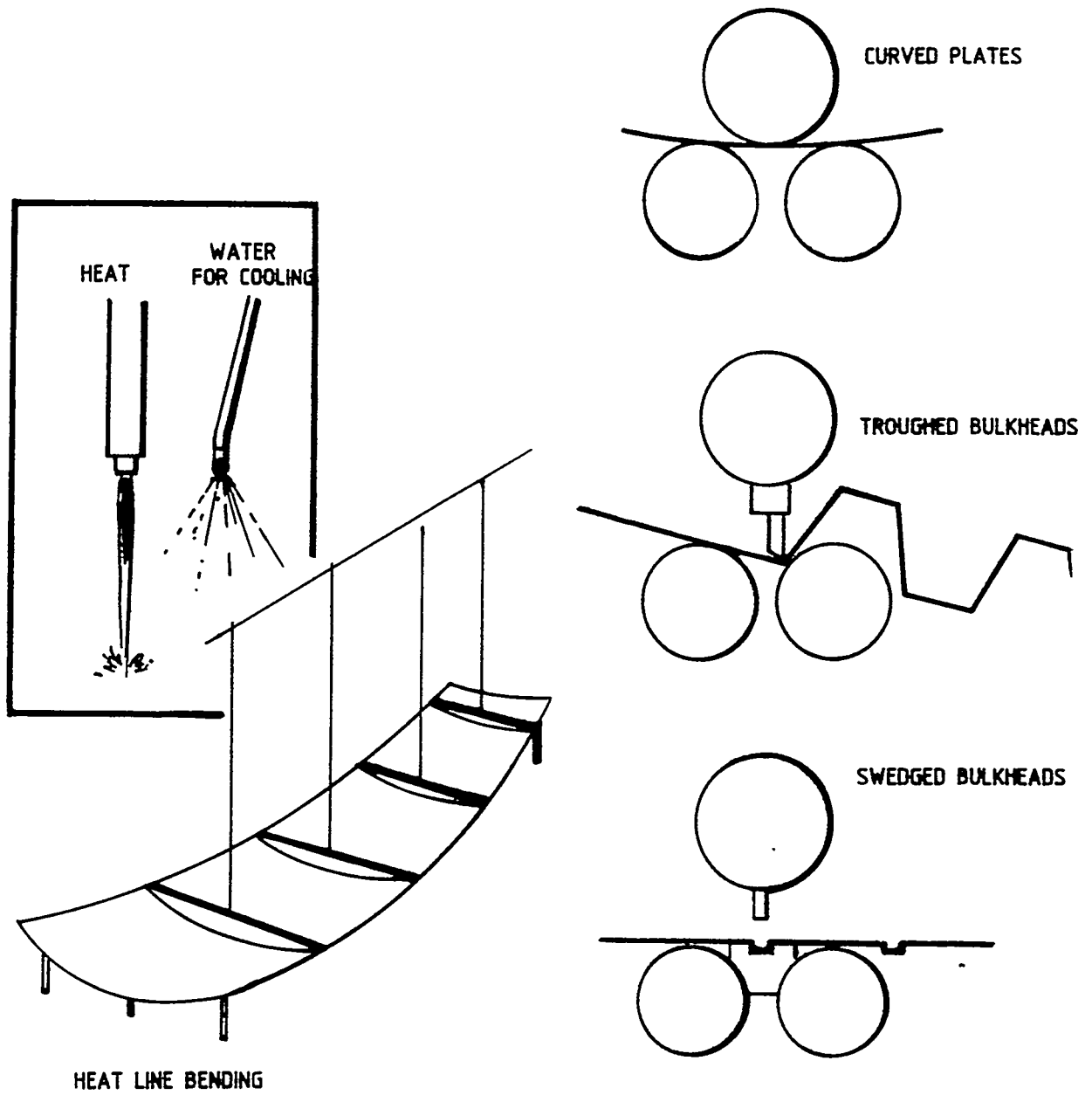
In addition to cold forming techniques many shipyards are using heat line bending techniques to-form plates, often in-conjunction with a shell roll or portal press.

The shell roll is used primarily for single curvature shell plate forming. Its capability for double curvature is limited, so some supplementary forming is necessary, which is best done using heat line bending. A shell roll may also be equipped with tooling so as to carry out flanging operations.

The flanging press is used primarily for forming corrugations for bulkheads. It is capable of forming parallel curved plates by successive pressing operations, but is very slow compared with the continuous rolling operation.

A portal press is a general purpose machine in which a plate moves under a fixed or moving press tool mounted under a portal frame. Although slow in operation, the portal press is capable of almost any forming operation. It is an ideal repair steelwork tool and can also be used for double curved plates, for example bulbous bows. A gap press performs the same function, but is lighter and better suited to smaller plates. The press brake is mainly used for troughing and flanging for superstructure bulkheads and brackets. A small roll is used for outfit steel.

The most important aspect of producing accurately formed plates is the type and quality of dimensional information, such as adjustable sight line templates and rolling lines. Computer aided generation of forming information is used based on the ship's hull form stored numerically in the computer.



## PLATE FORMING

### 2. 3. 1. 7 Shape Forming

Shape forming can be carried out either by cold forming or heat line bending. There will be a maximum scantling that a cold bender can handle; this limit will not apply to heat line bending although the cranes in the area where the work is carried out could be a limiting factor.

The main requirement for shape forming is for the bending of frames which are to be attached to the curved areas of the side shell. A secondary requirement is for shape straightening.

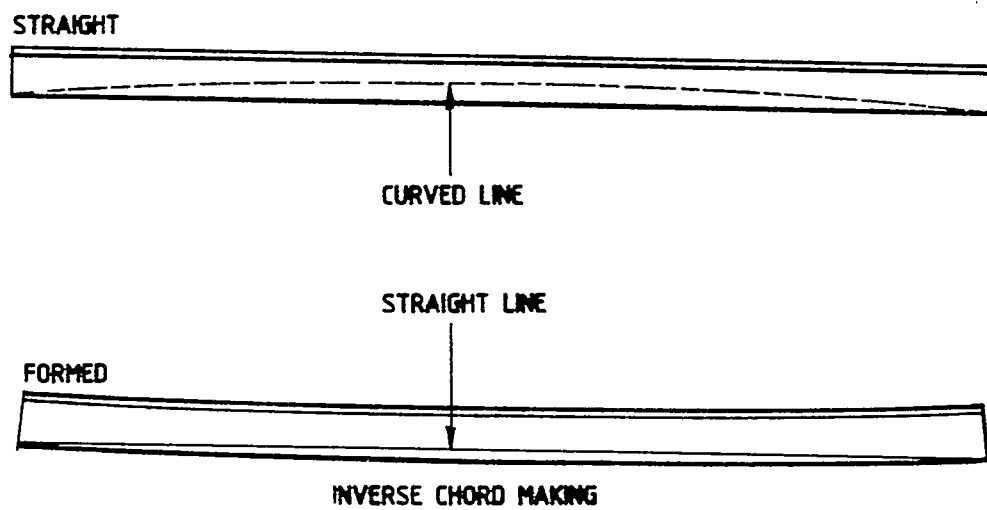
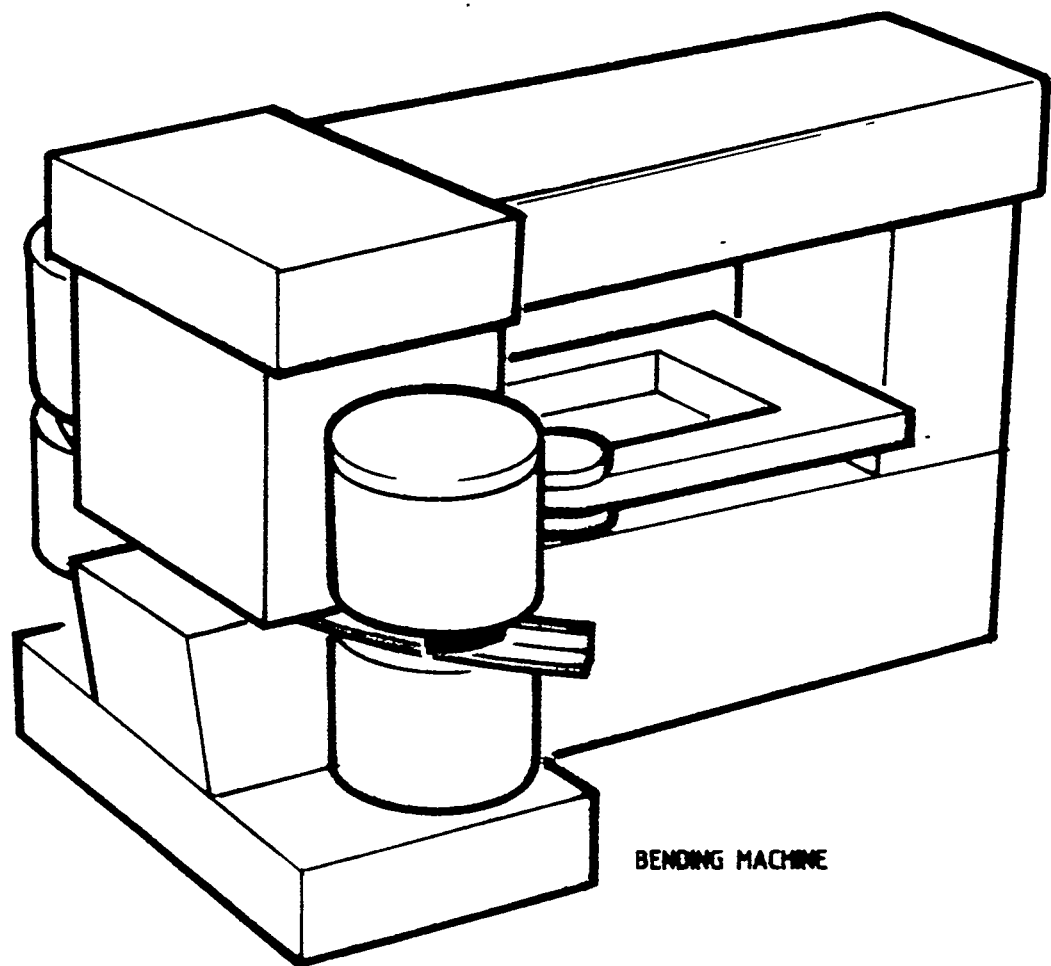
As a general rule, asymmetric shapes (such as angles, flanges or beams) tend to distort as they cool after hot rolling. Some steel mills cold roll shapes after hot rolling, in which case the shipyard should not have to perform much straightening. Inevitably, however, some shapes become damaged during transport and storage. These shapes should be straightened before fabrication.

Furnace forming methods and flame straightening are not used as they are very labor intensive; the bulk of shape bending/straightening is done by cold frame bending machines capable of bending shapes in both directions without their being removed from the machine.

Although numerically controlled shape bending machines have been produced for use in shipbuilding, they have never gained wide acceptance, even in shipyards with a very high throughput.

Inverse chord marking by machine or from full size lofted dimensions is an effective way of achieving accuracy, rather than using templates. For inverse chord marking, a curved line is marked on the shape, which, when the shape is correctly bent, becomes straight.

Flat bars which require to be bent to form face flats can be bent using the small roll (plate forming machine) or a horizontal pin press.



# SHAPE FORMING

### 2. 3. 1. 8 Minor Assembly and Subassembly

Minor assembly and subassembly are the first two stages in the joining of cut steel parts to produce steel units.

The designer needs to be aware of the size, weight, general configuration and work content associated with the work stations available for the production of minor and sub-assemblies. This is to ensure that a balanced flow of work can be generated through these work areas.

A minor assembly typically consists of an internal plate part with a face plate and minor stiffening, such as a floor, web, girder or bracket. They are produced in large quantities, and the principles of group technology can be applied to their production, whereby minor assemblies of similar size, work content and work process flow through pre-defined work stations.

The assembly of these interim products is assisted by the use of custom made jigs and fairing devices for rapid positioning of the parts before welding is carried out.

A subassembly is typically a number of minor assemblies joined together such as a matrix of double bottom floors and girders. Work station organization is used for the production of subassemblies and again purpose made jigs and fairing aids are used for rapid assembly.

Welding of both minor and subassemblies is mainly fillet, with very little butt welding. Semi-automatic welding such as MIG is used extensively and, because the majority of welding is downhand and fillet, gravity feed welding can be readily used.

#### 2.3.1.9 Flat Unit Assembly

Flat panels will be designer! such that they make optimum use of covered and craned assembly area. Consideration must also be given to the capacities of crange and transportation systems. In the ideal situation the optimum plate size for the treatment facility and cutting machines will be that which will give best use of panel lines or panel assembly area. This may not be so in a particular shipyard and in this case a decision mmst be made on the best sub-optimum panel or plate size for the shipyard. The designer must then work to the panel size agreed.

The proportion of the ship which is made up of units with a flat base obviously varies according to ship size and type. For large bulk carriers and tankers up to 60% of the steelweight can be flat units, while for small ships it may be just decks and bulkheads which are flat. The common procedure for flat unit assembly is as follows:

Plates are faired, tacked and welded together to form a flat panel

Major stiffeners are faired and welded to the panel to form a stiffened panel

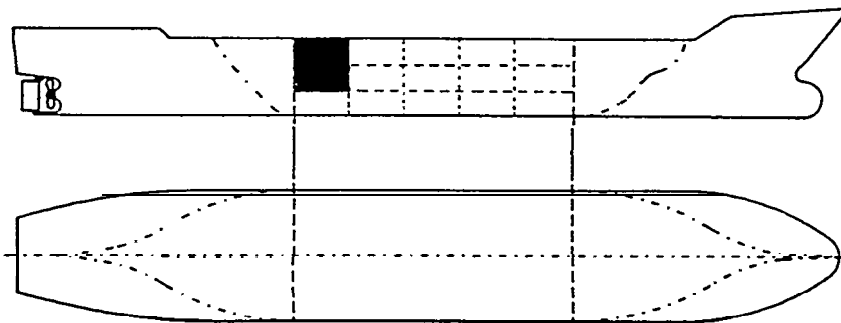
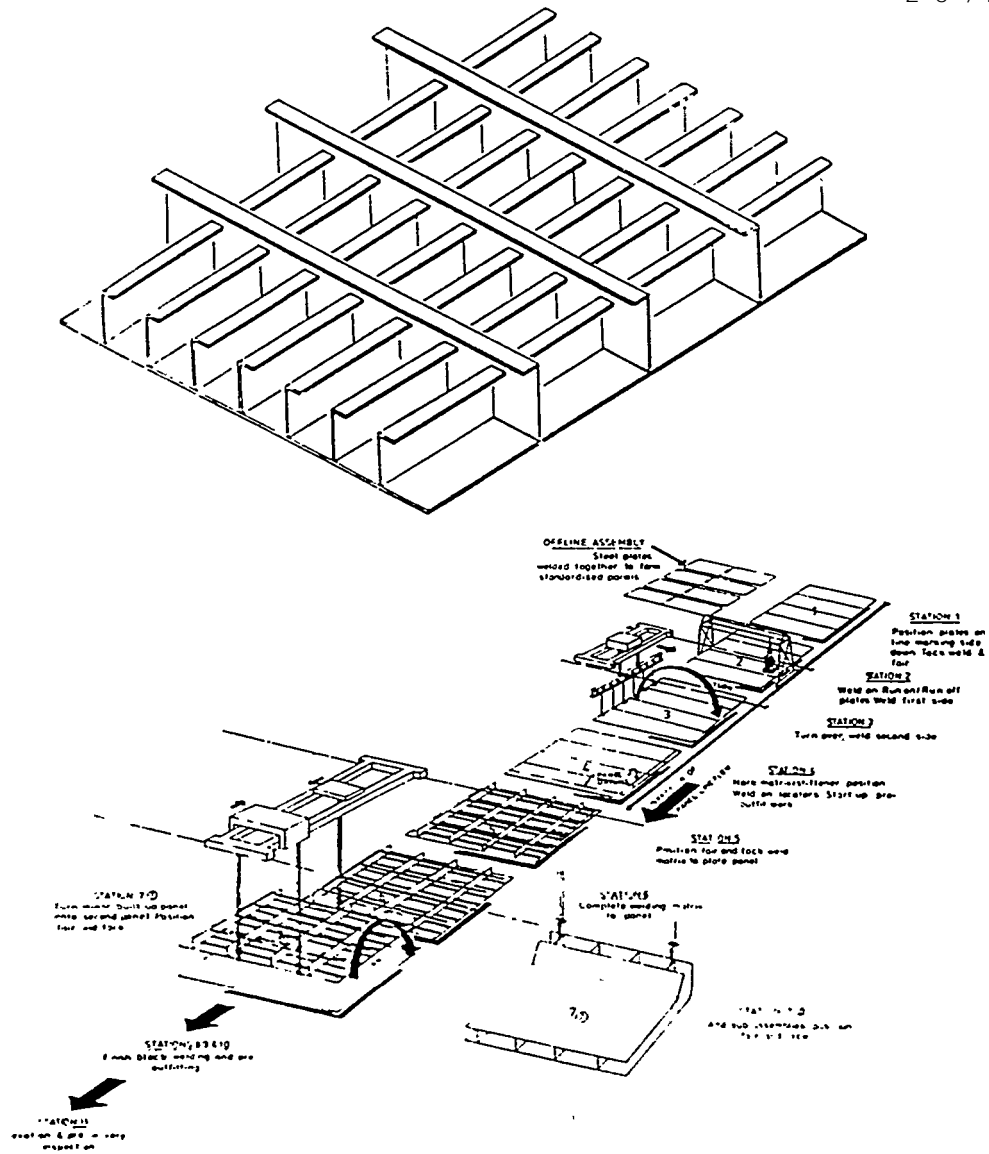
Secondary structure in the form of sub-assembled floors, girders, transverses or webs are faired and welded to the panel to complete the flat unit to form a built-up panel.

Mechanized panel assembly lines were introduced into some shipyards specializing in large tanker work. These lines generally have plate positioning and alignment systems, gantry or tractor mounted butt welding equipment, automatic shape injection and fairing machines and gantry mounted shape twin fillet welding equipment. Units are then either built-up on an extension of the line or in fixed positions in an assembly workshop. However, such equipment, although giving very high productivity, is not flexible with regard to the size and type of vessels that can be produced.



An alternative method of building up the flat panel is by the matrix method. This method is extensively used in Japan but has not in the past been widely adopted for flat panel work in Europe. The technique involves building a matrix of the longitudinal and transverse stiffeners and sub-assemblies in a jig which locates and holds the elements of the matrix. The elements are then welded together and the complete matrix is placed on the flat panel for fairing and welding to the panel. The welding of the rectangular "eggbox" cells of the matrix to the plate can be purely manual or by remote controlled automatic welding heads or by one of a number of intermediate methods.

Flat unit assembly provides a good opportunity to use automatic or mechanized production equipment. The process analysis of a vessel should maximize the use of available flat structure to form units which can use the equipment available.



FLAT UNIT ASSEMBLY

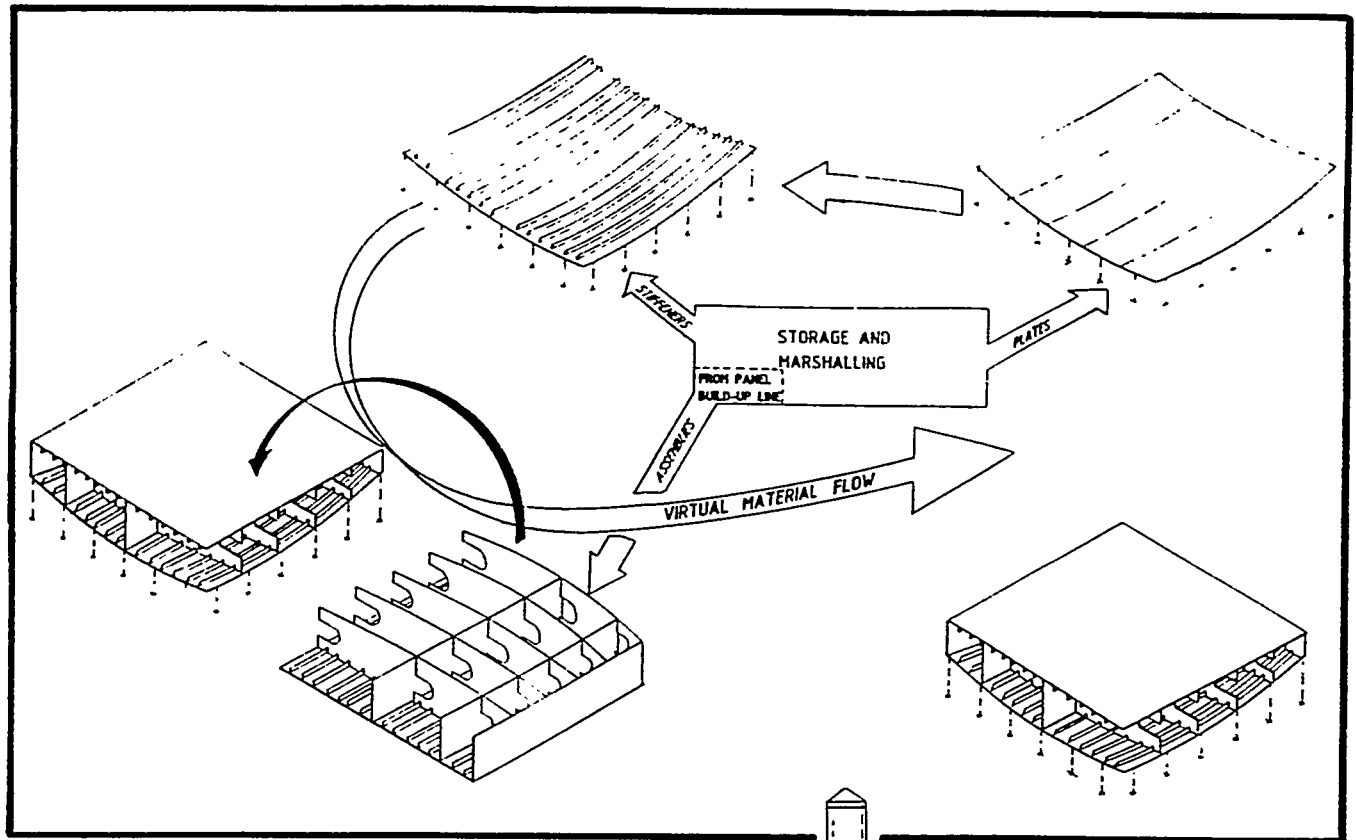
### 2.3.1.10 Curved and Corrugated Unit Assembly

As with flat panels, curved and corrugated assemblies must make optimum use of the available covered and craned area. In the case of curved assemblies, pin jigs or other fixtures should be available. The size of the curved assemblies most directly relate to the size of the jig and capacity of craneage in the area. Again, as with the flat panels, the curved assembly jig should itself be a function of the optimum plate size. This may not be the case, as in yards that have developed their facilities over a period of years without ensuring that balance between facilities was maintained, in other words, the plate length best suited to the cutting and forming equipment may not match the dimensions of the assembly area available. Designers must be aware of the limiting criteria to which they must work. It is of no use to use a maximum length plate in the treatment area, on its own a reasonable enough decision, if this leads to units or blocks that cannot be efficiently lifted, turned or transported.

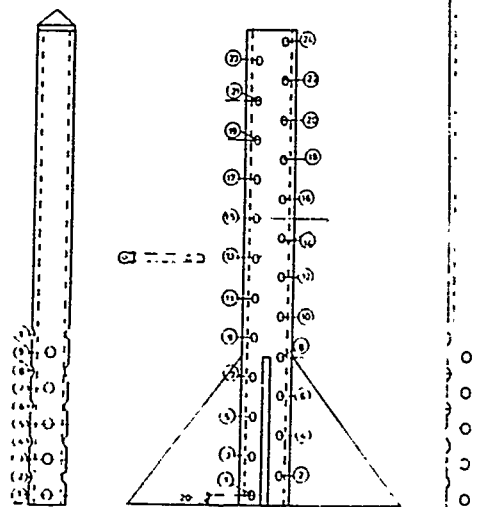
The amount of curvature in the shell of the ship varies according to ship type and size. All ships, with the exception of simple barges, have some curvature and the assemblies which make up the curved portion of the ship generally consist of shell plating with stiffening, together with one or more small flat panels or subassemblies.

Certain internal units consist of corrugated plate panels plus small subassemblies. The transverse bulkheads of cargo ships, bulk carriers and small tankers often have a corrugated structure.

In basic shipyards curved plate panels are supported in improvised, non-adjustable rigid shell jigs, which are cut to produce a "cradle" for the curved 'plating. Alternatively, the complete internal stiffening is erected piece by piece to form the desired shape on to which the various curved plates can be fitted and welded. The designer must be aware of the method used, so that the internal structure can be tailored to best suit the desired fabrication method.



ADJUSTABLE PIN



CURVED SIDESHELL



CURVED AND CORRUGATED UNIT ASSEMBLY

These units are labor intensive and involve lengthy erection periods. The fixed jigs used in basic yards are not adaptable to different ships, or even different units of the same ship. Production of the jigs themselves is time consuming and involves considerable quantities of non-reusable material. Significant time and material can be saved by use of an adjustable pin jig. Adjustable pin height information can be generated automatically by computer. The time spent at the next joining stage greatly depends on the accuracy of these units and thus dimensional checks are continually carried out.

The use of temporary welds to hold piece parts in the jig is to be avoided. The extra work caused by the "scars" or surface marks left when the welds are removed results in unnecessary work and delays. Non-welded methods of fairing are used, such as magnet clamps, mechanical clamps, portable hydraulic jacks reacting on the jig or against the unit structure, and chain clamps.

In general, the construction of curved shell units cannot, be extensively mechanized, therefore work stations are established, equipped with adjustable jigs, fairing equipment, welding equipment, staging arrangements and suitable cranes, to improve production efficiency.

### 2.3.1.11 Outfit Steelwork

As far as outfit steelwork is concerned the designer must understand the stage of production at which outfit steelwork will normally be incorporated in the structure. In this way advantage can be taken of opportunities to use the structure itself to best advantage, for example to provide access to the job and thus avoid the requirement for staging.

A wide variety of items come under the heading of outfit steelwork and the following list, although far from complete, gives an indication of the variety:

Deckhouse units.

Masts, derrick posts.

Cargo hatches, tanker hatches, watertight doors.

Foundations for deck machinery, main machinery, auxiliaries, pumps, minor machinery.

Framework for outfit units.

Pipe supports.

Bulwarks.

Small tanks.

Steel ladders and walkways.

Penetrations.

Similar types of work are grouped together into defined work stations where the appropriate jigs, fixtures, manipulators, fairing aids and automatic and semi automatic welding methods are applied. Standards are well developed to enable early ordering of material and estimation of work content, and to reduce the amount of design and drawing work.

### 2.3.1.12 3D Unit Assembly

The manufacture of 3D assemblies is an off-flow activity for the most part. The most important decisions will hinge around the assembly method. For example, from which surface will the assembly be built? Is it possible to include standard curved panels in the structure rather than using a conventional plate by plate approach? The design of the assembly must incorporate as many standard products from earlier stages as possible. The outfit content must also be considered. From a facilities and production point of view the designer must be aware of areas, crane capacities and welding methods.

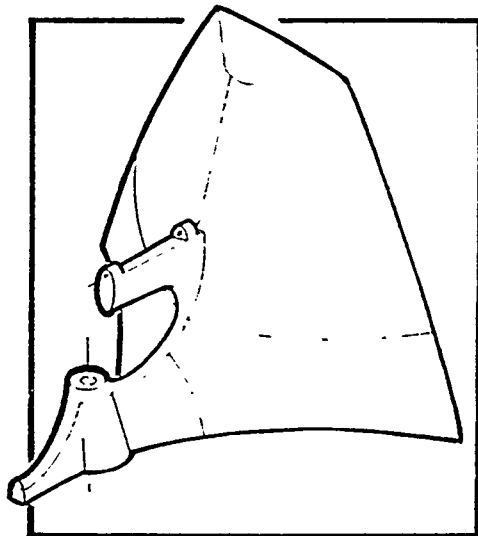
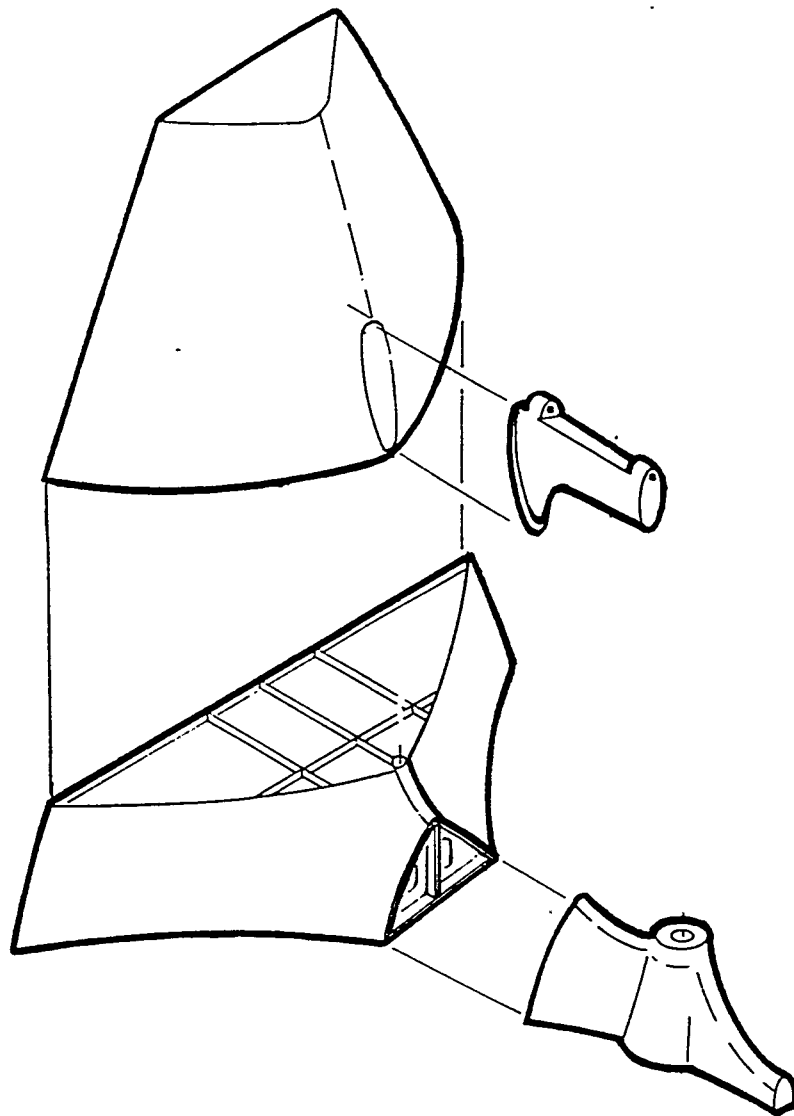
Those structures which are not built up from flat or curved panel assemblies are assembled as 3D units.

There are only a few 3D units in each ship but they are characterized by taking a relatively long time to assemble and are thus produced "off flow" in larger areas separate from those units which are produced "on flow" in larger quantities.

The breakdown of the ship is arranged so that 3D units have a flat side, off which they are built up, such as the collision bulkhead for a bow unit or the steering gear flat for stern units. To enable good dimensional accuracy these units are built on a level surface, preferably a few feet off ground level.

The units are assembled from a number of sub-assemblies and parts, the sequence arranged so as to achieve a high degree of downhand work and provide good access to the unit for as long as possible. For units with heavily curved shell plates the internal structure is used as a jig on to which the plates are faired, tacked and welded.

When these units have to be turned after assembly, the turning arrangements are planned so as to ensure that the operation is within the limits of the existing craneage.



3D UNIT ASSEMBLY



### 2.3.1.13 Outfit Manufacturing and Stores

In all outfit production areas the aim of the designer must be to reduce the variety of parts to be made. This can be done by developing and using standards and identifying families of products that have the same or similar production processes.

In the pipework area there is one basic truth - the easiest pipes to make are the straight ones. Designers must therefore make every possible effort to design pipes that run along straight pipe routes or ducts. Any designer walking round a pipe shop or onboard the ship can evaluate the number of pipes that are straight and ask how the number or percentage can be improved. In most ships there are good examples of even large diameter pipes snaking all over the ship. Designers must eliminate this wherever and whenever possible. Chapters 2.2.2 Contract Design and 2.2.4 Transition Design cover this aspect.

Examples can be found in other areas; are there yard standards for cabin arrangements and furniture, does vent trunking in the engine room follow the same basic orthogonal routes as pipework and so on?

Designers should take every opportunity to spend time in the shipyard during outfitting to see what is going on and to ask himself how it can be improved. These visits should supplement any training or management development and the formal information feedback systems discussed in Chapter 2.3.4.

#### 2.1.3.14 Fitting & Machine Shop

The engineering function can be conveniently divided into machinery for the installation of the main propulsion and shafting systems and all auxiliary machinery requirements for main engine and domestic services. Installation of the main engine usually involves the re-assembly of an engine which has been built and tested at a main engine builder and then broken down into a series of smaller pieces which can be transported conveniently. The re-assembly and setting up of the engine involves the manufacture of small parts required to finalize setting and alignment and these are conveniently manufactured in a small machine shop within the yard. Connecting services to the engine, pumps, compressors and alternators can also involve the manufacture of small items.

The hull engineers are generally responsible for the installation of cargo handling systems, deck machinery and similar items. Small part manufacture is also required for this section.

The installation sequence for much of the engineer's equipment has changed in recent years with the introduction of the concept of advanced outfitting. Traditionally, very little installation work was carried out while the steelwork was being erected. Advanced outfitting techniques have changed this and it is now common practice to outfit steel units before erection on the berth. In this position, access for outfitting is greatly improved and materials handling is much reduced.

The engineering installation function has therefore been brought forward with the consequent reduction in shipbuilding cycle times. This technique has been used successfully on large vessels, but access problems on small ships can curtail its use.

### 2.3.1.15 Pipework

Pipe manufacture is organized using the principles of group technology, whereby pipes are grouped for similar processing into "families", such as by shape (straight/bent/branched), and by diameter and by material. The pipeshop is organized so as to produce these families of pipes in a number of flow lines.

The stages of pipe manufacture are:

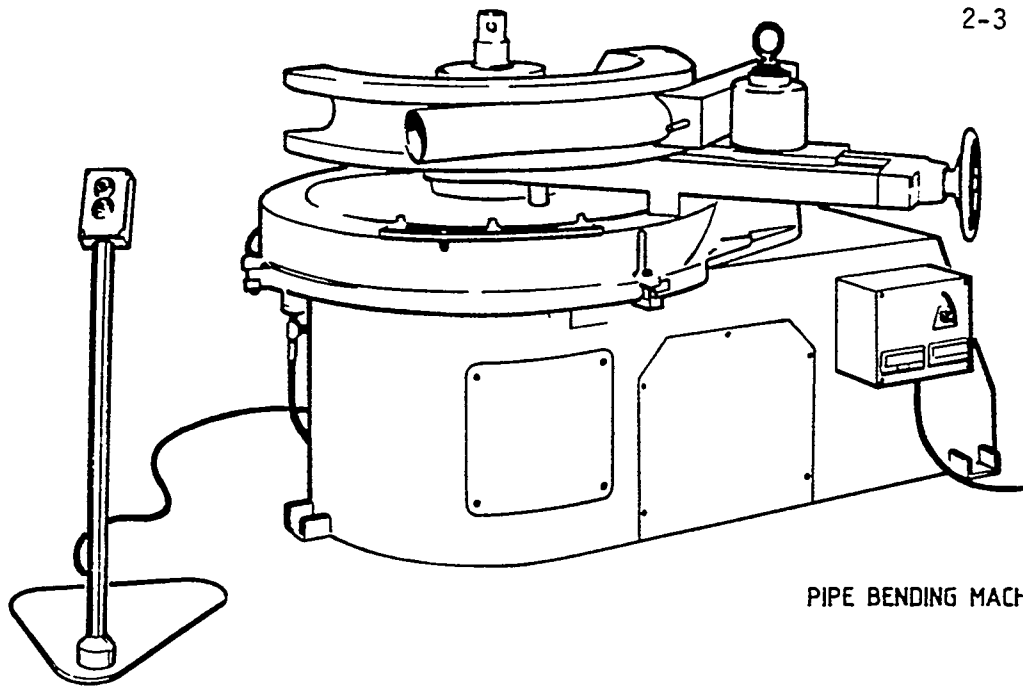
- Storage
- Treatment (blasting and painting)
- Marking and cutting (cold saws or burning machine)
- Flange-Welding
- Bending
- Assembly/Welding
- Testing
- Cleaning
- Coating
- Marshaling

All of these stages can be automated to a greater or lesser extent, depending on the required throughput and productivity ambitions.

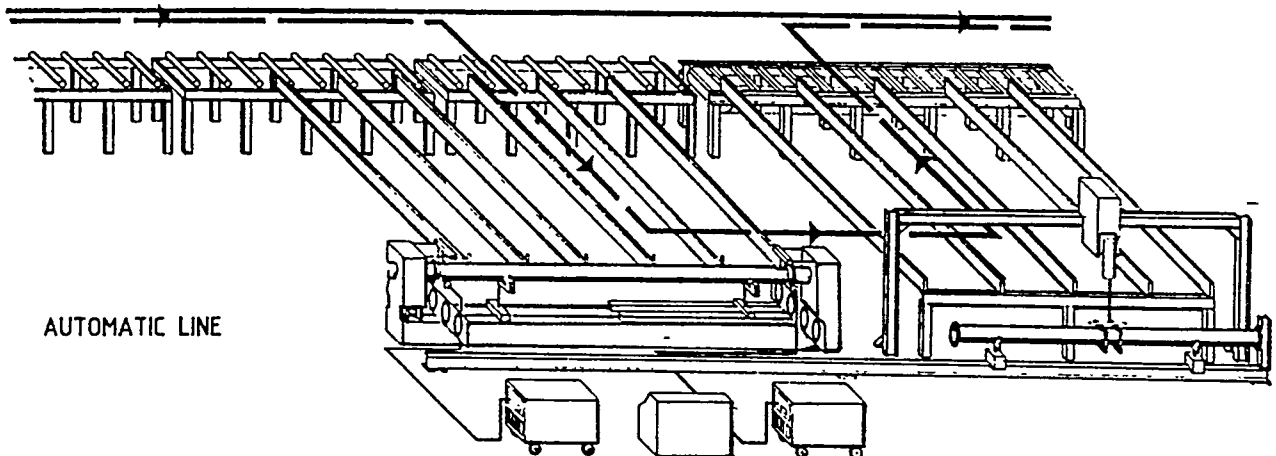
For high production rates and maximum productivity, fully automated production lines with NC cutting, NC flange welding and NC bending are used. These machines are linked by automatic conveyors and loading and unloading devices.

Automated or semi automated pipe production systems are most efficient when the flanges are welded before bending, as then the majority of pipes are straight until the end of the fabrication process and handling and machine welding is thus easier.

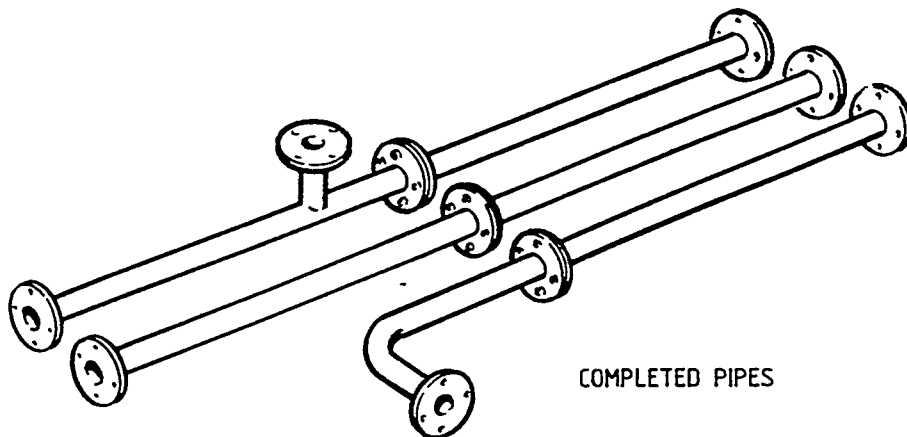
Information for up to 90% of the pipes is provided direct from design drawings, either manually produced or automatically where a CAD/CAM system is used for pipework design and definition. The remaining pipes are produced from sketches produced at the ship, such as "closers or spool pieces", that is, pipes which are fitted on-board between adjacent outfit assemblies.



PIPE BENDING MACHINE



AUTOMATIC LINE



COMPLETED PIPES

#### 2.3.1.16 Electrical

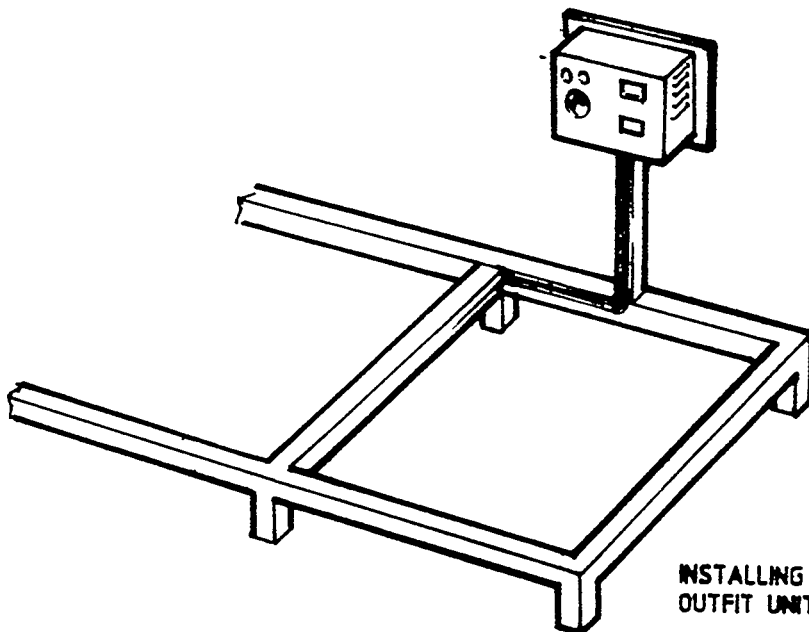
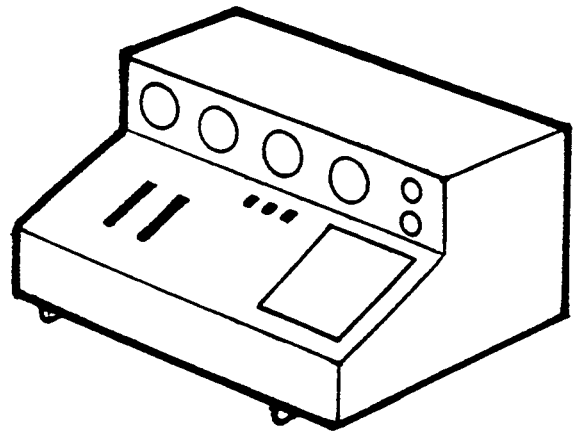
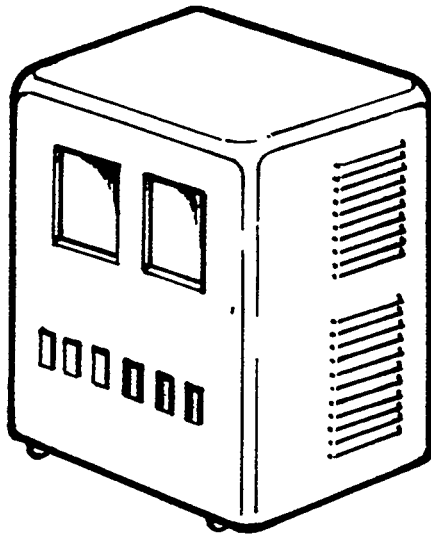
Shop electrical work consists mainly of console and switchboard manufacture and wiring of outfit assemblies before installation.

Console housings or cabinets are purchased or are produced in the sheet metal shop and then transported to the electrical shop for the installation of instruments, etc. A console test facility is used for testing and calibration of electrical equipment and instrumentation before installation onboard ship.

An area of the shop is also used for minor manufacturing operations, and is equipped with simple facilities such as drills, punches and hand tools.

The second major activity is the fitting of electrical equipment to outfit units after the heavy outfit items such as pipes, pumps and valves have been installed. Typically, outfit units have starter boxes, lights, switchgear and alarm systems fitted and wired before installation. Cables which are routed off the outfit unit are wired into the outfit unit to as great an extent as possible and are then cut to approximate length and coiled. After installation the free end is then "pulled" to its destination.

CONSOLES



INSTALLING EQUIPMENT ON  
OUTFIT UNITS

### 2.3.1.17 Sheet Metal Work

This material typically under  $\frac{1}{4}$  thick is classified as sheet metal and is used for the following items:

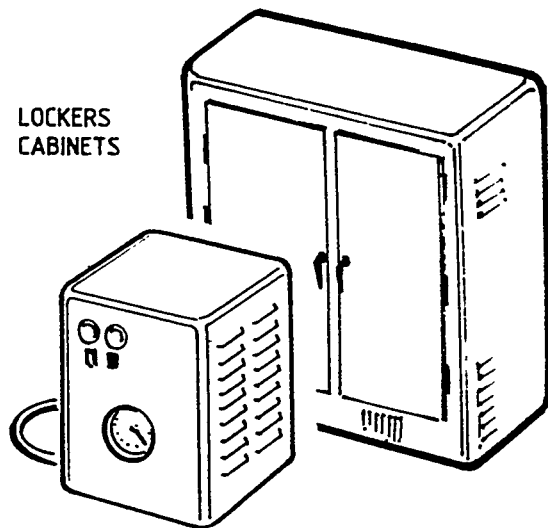
- Control consoles
- Main power distribution boards
- Switch boxes, junction boxes
- Lockers, cabinets and shelves
- Galley items
- Ventilation trunks and ducting
- Insulation cladding
- Furniture

The sheet metal shop consists of a number of work benches equipped with hand tools, such as drills and rivet guns and a number of machines used for cutting, forming, pressing and punching.

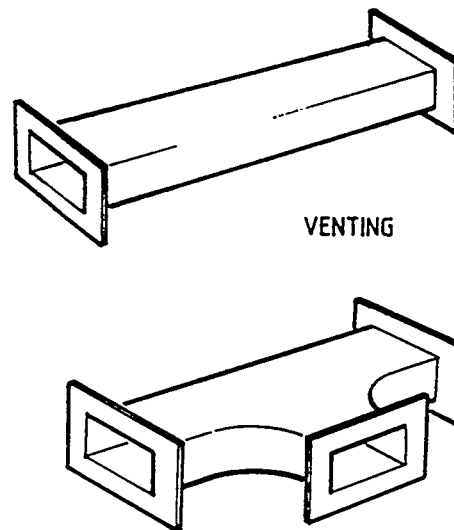
A press brake is used for the main forming operations to produce boxes and angles. These machines are small and light but with adjustable stops for batch production of similar components. A comprehensive set of tools is used with these machines for different forming operations. Guillotines are used for cutting sheet metal giving high accuracy and a good straight edge. A universal steelworker is used for cutting of small angles, tees and other sections which cannot be cut on a guillotine shear. A punch and shear machine is used for producing instruments cut-outs, in, for example, control console panels. These machines can be numerically controlled, template controlled or manually operated. More recently, plasma arc cutting has been applied to sheet metal work.

Historically, sheet metal work has involved manufacture of small items, followed by on-board installation where most of the manhours were expended. Increasingly, sheet metal work is fitted before erection, on steel units or as part of an outfit assembly. There is more emphasis on accurate manufacture, rather than on fieldwork.

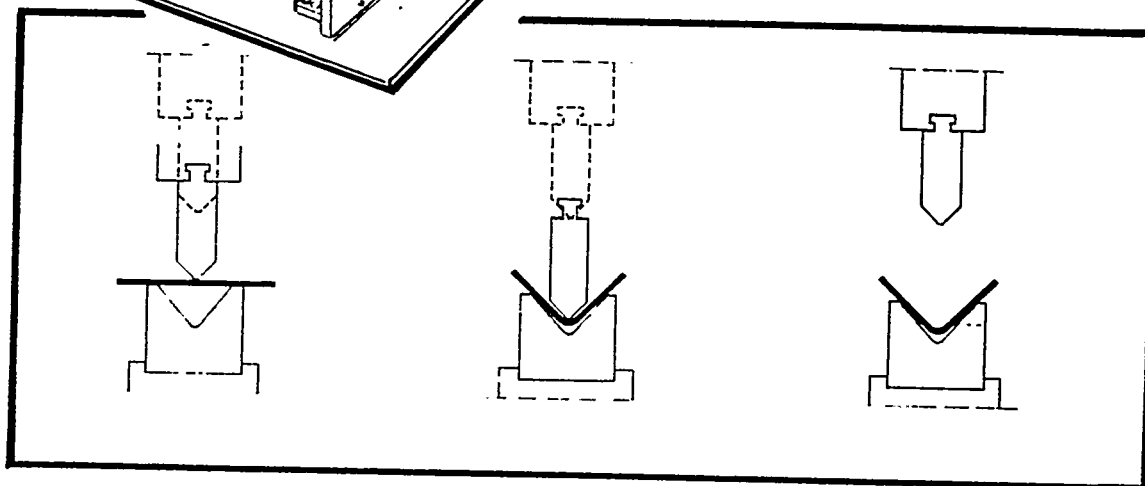
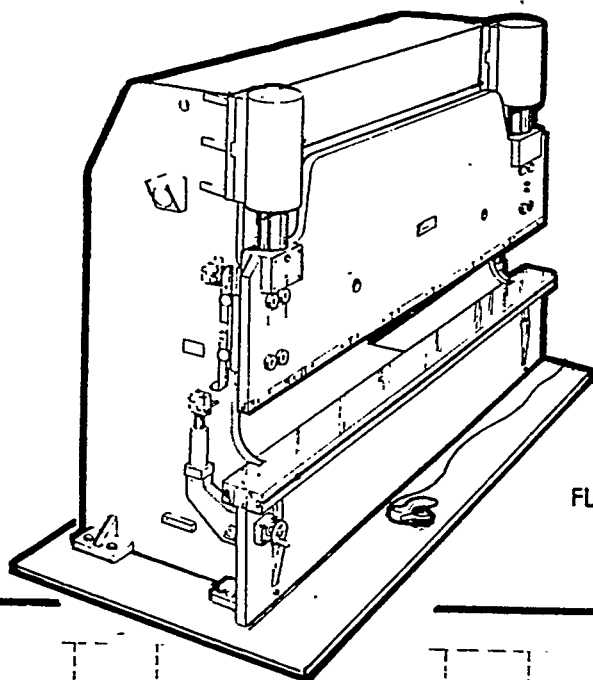
LOCKERS  
CABINETS



VENTING



FLANGING MACHINE



SHEETMETAL WORK



### 2.1.3.18 Woodworking/Joiner Shop

This paragraph considers woodwork in shipyards and can be divided into two categories - joinery and rough timber work. These may or may not be carried out by the same work group.

Rough timber work includes such types of work as ship support timbers, store room shelving, wood sheathing, trestles and sparring. The quantity and type of equipment and the methods employed depend upon the level and pattern of output. For small outputs, a shop would contain certain basic woodworking equipment such as circular saw, cross cut saw, planer/thicknesser and sander. There is considerable use of hand tools in the shop.

Joinery includes the production and installation of all wood or synthetic material furniture, bulkhead panels and interior fittings with the majority of the work in the accommodation spaces.

When the dimensions of wood furniture and individual components can be standardized and larger quantities are required, batch production methods can be applied successfully. Cut timber is stored on purpose designed racking and handled by fork lift trucks. The wood preparing machines are grouped together in a specific arrangement of sawing, planing and detail cutting machines. A separate area is used for preparing panel items. This grouping of machines simplifies such things as dust and refuse collection and has the advantage of keeping noise making equipment isolated in a separate area.

There is an assembly area for the products, and the finished units or batches of panels are stored on pallets. The size and workload of the shop depends on the degree of bought-in prefabricated items.

### 2.3.1.19 Warehousing

The functions of the warehouse can be summarized as follows:

To provide an area in the shipyard-for reception, storage and dispatch of bought in goods.

To provide a buffer between ship production demands and subcontractors supplies and to produce a flow of materials, components, tools and equipment to the various production departments as required.

To provide an area where materials can be placed under cover, if required.

To prevent pilfering of items that are in storage.

To provide maintenance materials, other than spare parts, and general stores as required.

Shipyards have to store a large number of items for each ship. These range from large items such as engines, lifeboats, and engine room auxiliaries, to small items such as special valves and fittings. The variety of items to be stored is considerable and no one method of storage can satisfy all requirements. Similarly, the operating systems must be sufficiently flexible to effectively control movement of a great variety of types and quantities of materials.

The items held in the-warehouse include:

Ship's outfitting items, bought in or manufactured in house.

Owner's supplied items.

Consumable stock items such as electrodes, flux, wires, nuts, bolts, nails and so on.

All material, excluding steel plates, shapes and pipes is identified. sorted and documented at the warehouse receiving area prior to being placed in storage. The steel plates and sections are controlled from the stockyard. After documentation, paint would be sent to a special storage area.

#### 2.3.1.20 Pre-Erection Activities

Historically, shipbuilding consisted of manufacturing of both steel and outfit items, and construction or installation. However, there are now a number of additional pre-erection activities which take place between manufacturing and installation.

These activities primarily involve the installation of outfitting at an earlier stage than is traditional. Steel units may also be combined into larger blocks, for example the deckhouse, which can also be extensively outfitted before erection.

The significance of these changes to the designer lies in the different needs for information which they generate. The traditional system-based information which on-board workers used and which gave considerable discretion to production to field run systems, has to be replaced. The form of information required develops composite drawings of specific zones of a vessel. The locations of all systems are pre-defined.

It is essential that the designer is fully aware of the processes used in a shipyard to allow him to tailor his information to the requirements of production.

#### 2.3.1.21 Outfit Parts Marshaling

Outfit work, whether on outfit unit, on steel unit or onboard ship, is divided into work packages. The means for organizing this work is the material list of fittings for each work package.

The outfit parts are collected into their work packages as defined by the material list and are taken to the appropriate area when the work is due to start.

During manufacture outfit items are produced in a manner which is most efficient for the shop, (such as family manufacturing of pipes). Then, through the collection process, outfit items, possibly from more than one trade, are gathered together according to the needs of outfit installation.

Physically, collection of outfit parts is done using pallets, of either steel or wood, which can be clearly identified to a work package. These pallets are readily handled by fork lift trucks which deliver the parts to the assembly or installation area via roads and accessways within the shops.

The strict use of pallets also leads to good housekeeping and makes storage and organization easier within shops.

A labelling system is used for quick and easy identification of pallets and work packages.

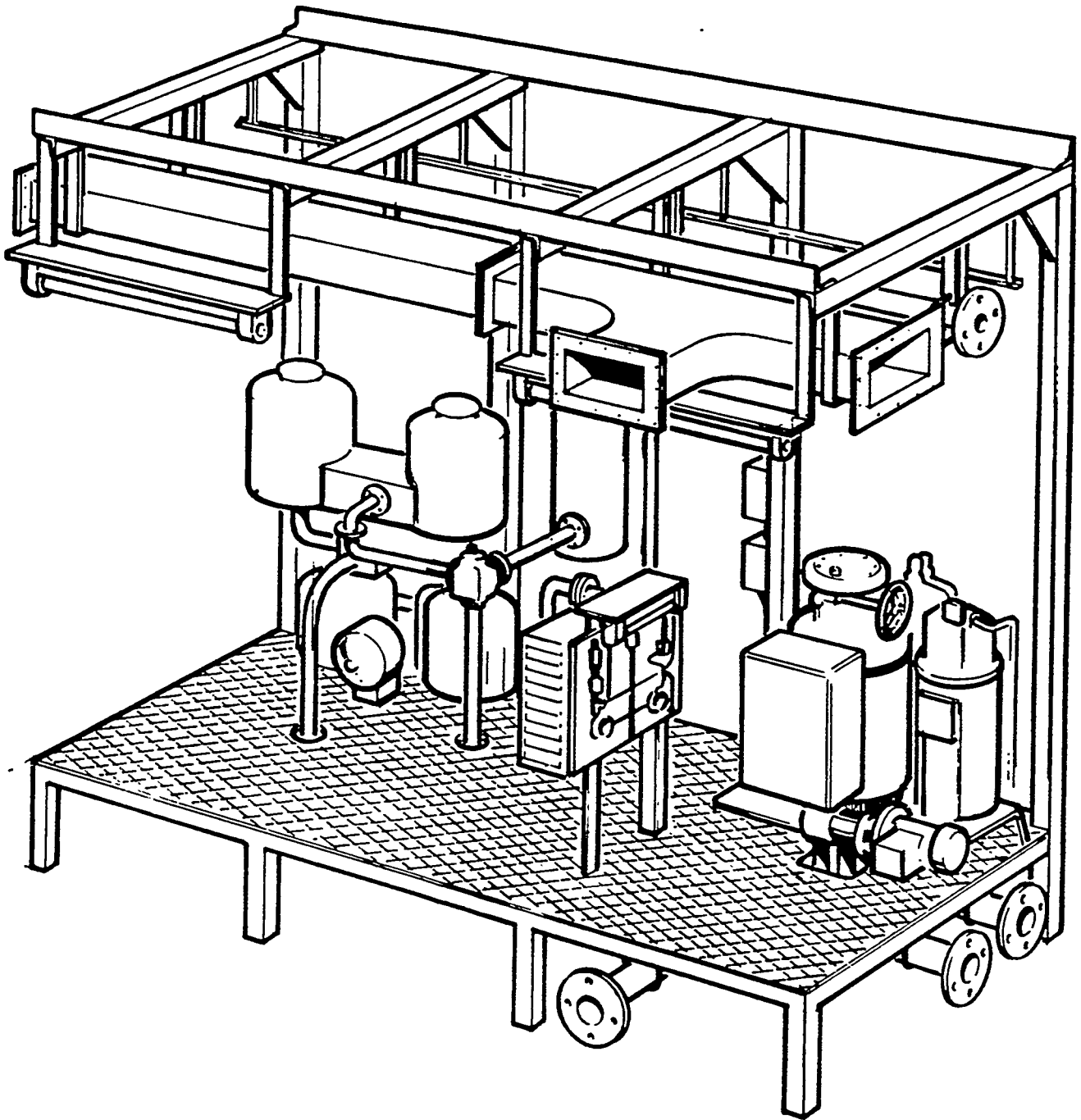
#### 2.3.1.22 Outfit Unit Assembly

Outfit unit assembly, similar to steel unit assembly, is broken down by a process analysis into hierarchical stages of interim products.

The units are assembled at a number of outfit workstations in a shop with sufficient crane capacity and door size for the largest units which the product range demands to be lifted and removed.

The outfit units are made up of a number of outfit subunits, outfit subassemblies and outfit parts. These interim products are best divided by craft into subassemblies of pipes, vent trunking or steel framework. The subassemblies are joined to create an outfit subunit which is a steel framework, complete with equipment, pipes, venting and floor plates. Electrical equipment is then added and wired. Subunits may be joined into outfit units.

Inspection, painting and testing, where possible follows fabrication and assembly before the outfit unit is installed.



OUTFIT UNIT

### 2.3.1.23 Superstructure Unit Assembly

In general, Superstructure assemblies will be built outside rather than under cover. The area chosen is generally at the head or to the side of the building site.

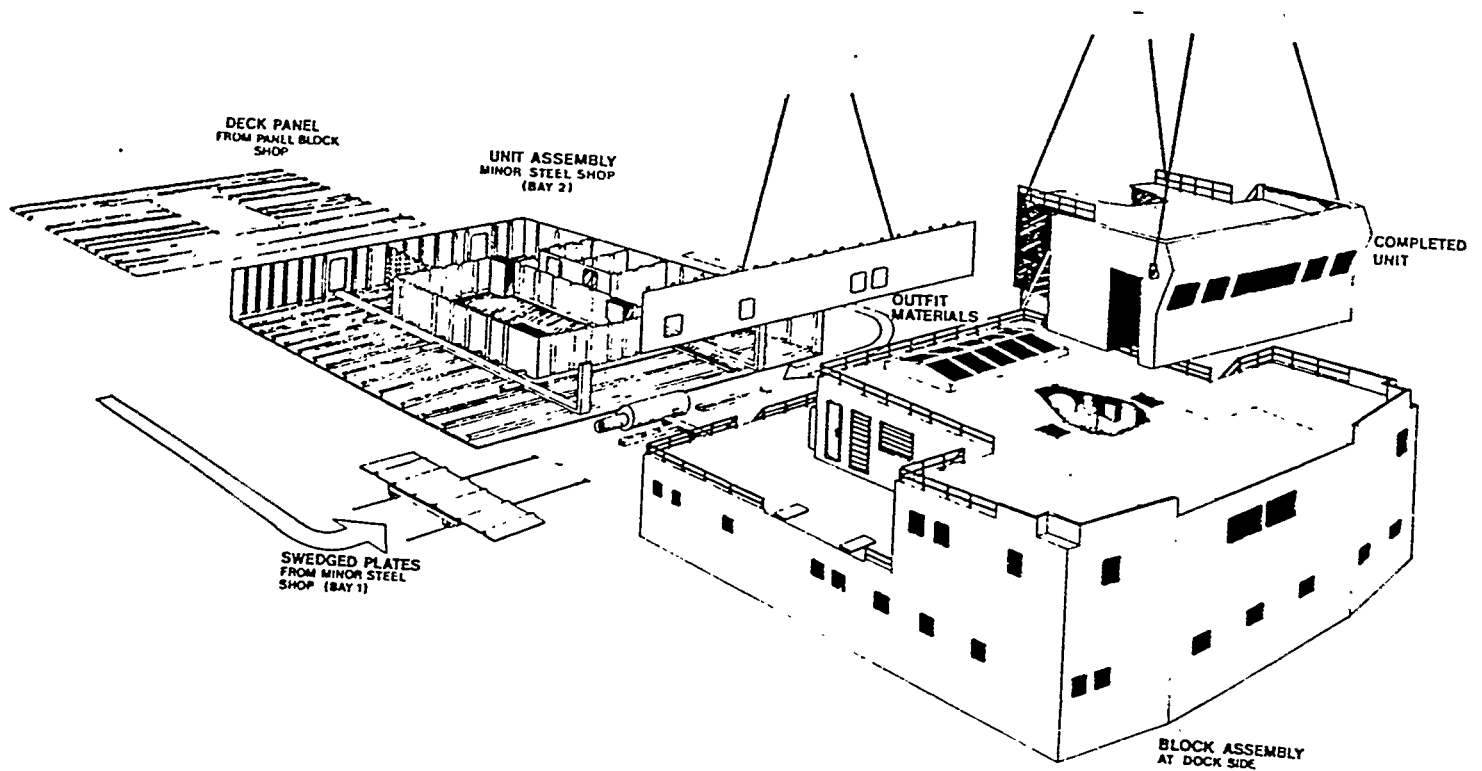
Superstructure unit assemblies are built up from deck and bulkhead minor flat panels, which are either lightly stiffened or swaged: curved surfaces which have an inherently greater work content are avoided where possible. Because the superstructure is outfit intensive the build method is arranged so as to best suit outfitting. Each deck and the bulkheads under are built upside down and the deckhead painted and outfitted downhand before the unit is turned onto the deck below for further downhand outfitting.

Modular outfitting concepts are now used by some shipyards whereby completed modules such as wet space units or complete cabins are shipped into the completed superstructure and fastened into position. The maximum of outfitting is thus completed entirely independently of the ship's structure.

where possible, in order to shorten the build cycle, the superstructure may be assembled, painted and outfitted to a considerable extent separately from the rest of the ship and then erected late in the build program as a single block. A horizontal cofferdam below the lower deck of the superstructure allows the maximum amount of outfitting to be completed before erection.

The ability of a shipyard to erect the superstructure in one large block (or number of blocks) is of course limited by the available cranes at the building site. Some shipyards will use a mobile high capacity floating crane to carry out the lift after the ship has been launched.

The design has a subtle but important influence on the ability to lift and erect large superstructure units. The arrangement of compartments can make the unit sufficiently stiff to insure that the completed outfit work will not be damaged during erection.



SUPERSTRUCTURE ASSEMBLY



### 2.3.1.24 Block Assembly

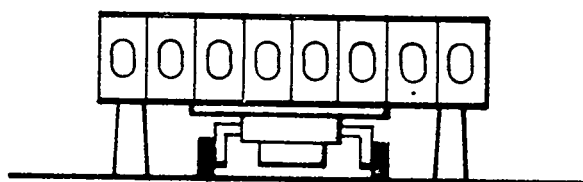
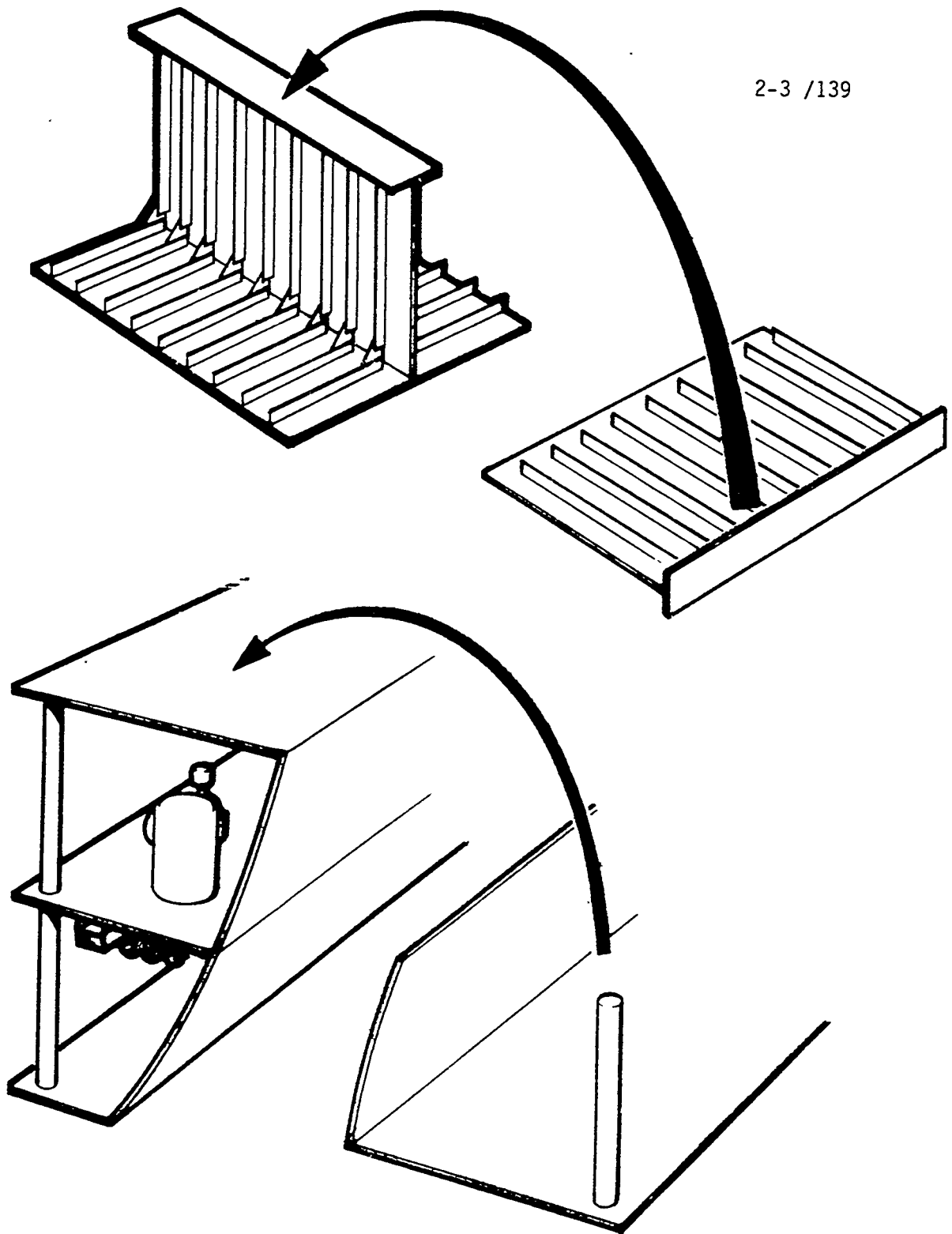
In order to reduce the volume of work to be done at the final construction stage in the dock or on the berth, units may be joined to, form blocks which are limited in weight and thus size by the available craneage over the final construction site.

At the block assembly stage the aim will be to maximize the work done prior to erection. It is the final chance to get work done off the ship while access is significantly better. It is at this point that it is essential that the end product matches the facilities. The block, with its ore-outfit content, should approach the maximum capacity of the berth or dock craneage. Ideally everything should be in balance, with the plate sizes best suited to the treatment line and all subsequent processes providing assemblies and blocks to the maximum capacity of berth craneage.

Blocks are assembled outside, either at the head or side of the berth under construction cranes or else in remote block storage areas. In the latter, arrangement units are transported and positioned next to each other using wheeled self-elevating transporters and then fine positioning is carried out using transporter capacity which should be compatible with the construction crane causing

The manhours spent at the block assembly stage is dependent on the accuracy of the finished unit; inaccurate units lead to excess material having to be left on one or more of the unit edges as well as increase joining time.

Once joined, final pre-erection outfitting and painting is carried out. Blocks can be serviced by lightweight mobile cranes leaving the main cranes free for block erecting work.



BLOCK ASSEMBLY

Apart from the production of outfit units, pre-erection outfitting consists of installing outfit parts and outfit assemblies on steel assemblies and units before they are erected. The main advantage of pre-erection outfitting is that work at this stage is relatively easy to carry out, with good access and the maximum of downhand work. Pre-erection outfitting typically consists of the installation of:

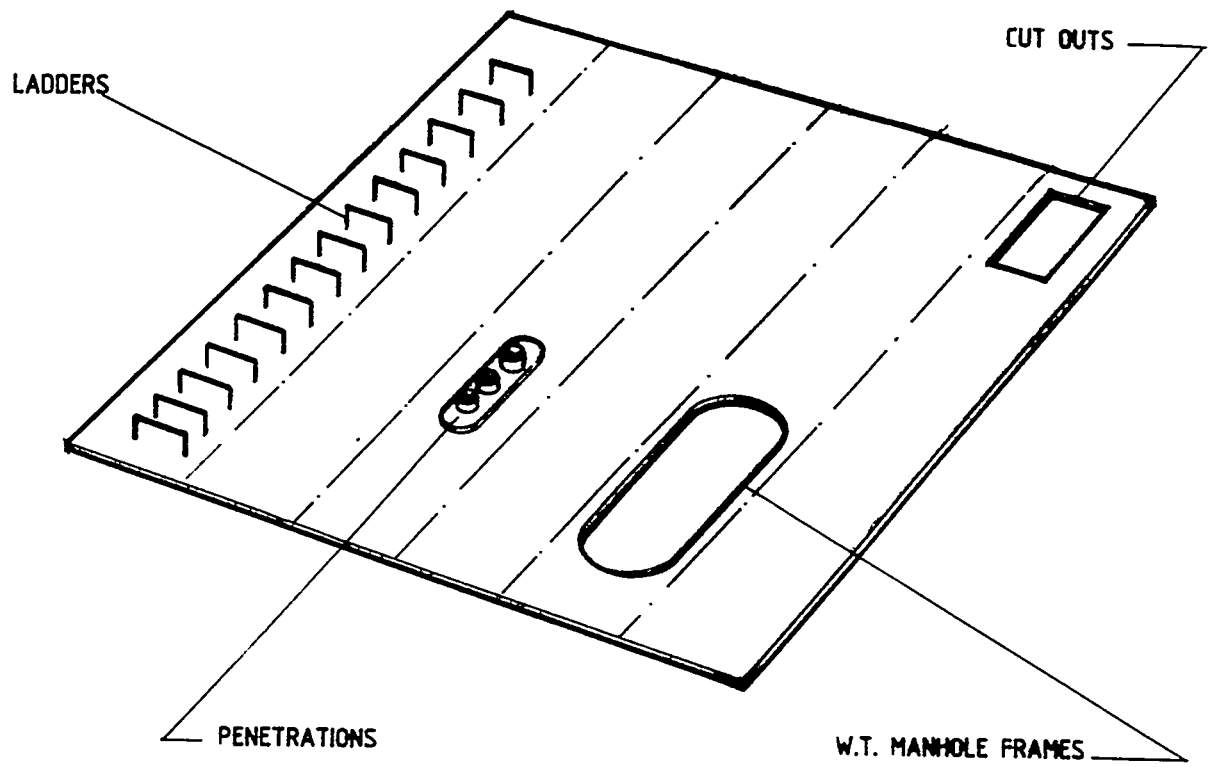
Minor steel work	- Ladders, gratings, manholes. WT doors, foundations, stanchions, handrails.
Pipework	- Deck, deckhead, bulkhead and double bottom outfitting of pipes or pipe assemblies.
Minor outfit	- Drain plugs, sounding pipes and caps.
Venting and cable trays	- Deckhead and bulkhead venting installed downhand.
Lights and wiring	- On mast units.

painting is integrated with Outfitting. throughout the build cycle in order to:

- Reduce the painting requirement at the berth or in the dock.
- Paint when access to the structure is good.
- Reduce staging requirements.

However, paint work is damaged by hot work such as welding and therefore to avoid excessive repairing/touching up of areas, the application of paint must be planned to allow completion of hot work in a zone but before the installation of outfit items makes access poor.

Some yards utilize paint cells in which units are shotblasted as necessary and have their paint under controlled atmospheric conditions. This is particularly important for specialized paint systems. Plate edges are taped where further welding is to be carried out. applied using airless spray guns, allowing fast and even application. The final external hull coat is normally left until late in the build cycle so as to give an even finish which will be in good condition when the ship is delivered.



#### 2.3.1.26 Unit and Block storage

Units and blocks may be stored underneath the construction storage, but this area is at a premium so self-aligning transporters are used which allow remote areas to be used for storage. Units or blocks are stored about 6 feet above ground level on stacks or trestles, thus allowing the transporter to drive in underneath the structure in order to pick it up without the need for a crane.

These storage areas are used for outfitting, painting and joining operations and are best served by lighted mobile cranes.

#### 2.3.1.27 Ship Construction and Final Outfitting

The ship construction stage has historically been the bottleneck of the shipbuilding process, and remains an area where work is carried out less efficiently than at the other production stages.

Two objectives in achieving efficient construction are apparent. The first, is to reduce the work to be completed at the construction stage, primarily by assembling large, accurate steel and outfit units and adopting pre-erection outfitting methods. The second objective is to make the work that has to be done as easy as possible.

Multiple stage construction techniques such as semi-tandem construction can be adopted, whereby for a given cycle time, there is twice the time available for construction and outfitting of the stern part of the ship containing the majority of outfit work.

Traditionally, ships were constructed on inclined berths, which have the advantage of low capital cost. The disadvantages of constructing ships on a slope or incline are in maintaining accuracy since corrections are needed for vertical and horizontal surfaces due to the declivity of the shipway.

Building docks allow more than one ship to be built at a time, level construction and easy launching (float out).

More recent developments in the art of moving very large and heavy objects has led to the developments of ship lifts and ship transfer systems, allowing vessels to be built remote from the water on level construction areas, and then moved and lowered into the water mechanically, giving excellent flexibility at the construction stage.

### 2.3.1.28 Erection and Fairing

The ship is constructed by erecting units or blocks with the dock or berth craneage. An erection program is planned at an early stage to give a steady rate of erection so that the labor squads can be most effectively organized.

The accuracy of units or blocks being erected has a considerable effect on the rate and smoothness of the erection program. An ongoing objective is to reduce the time spent fairing inaccurate units or blocks by improving construction.

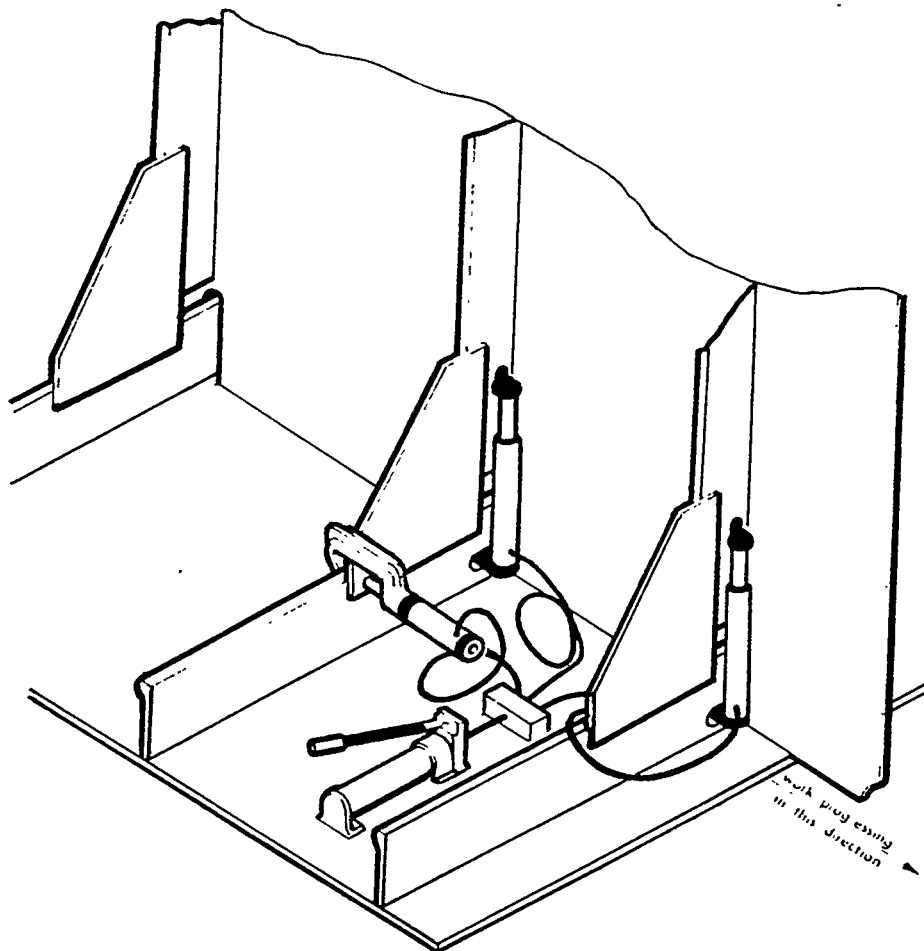
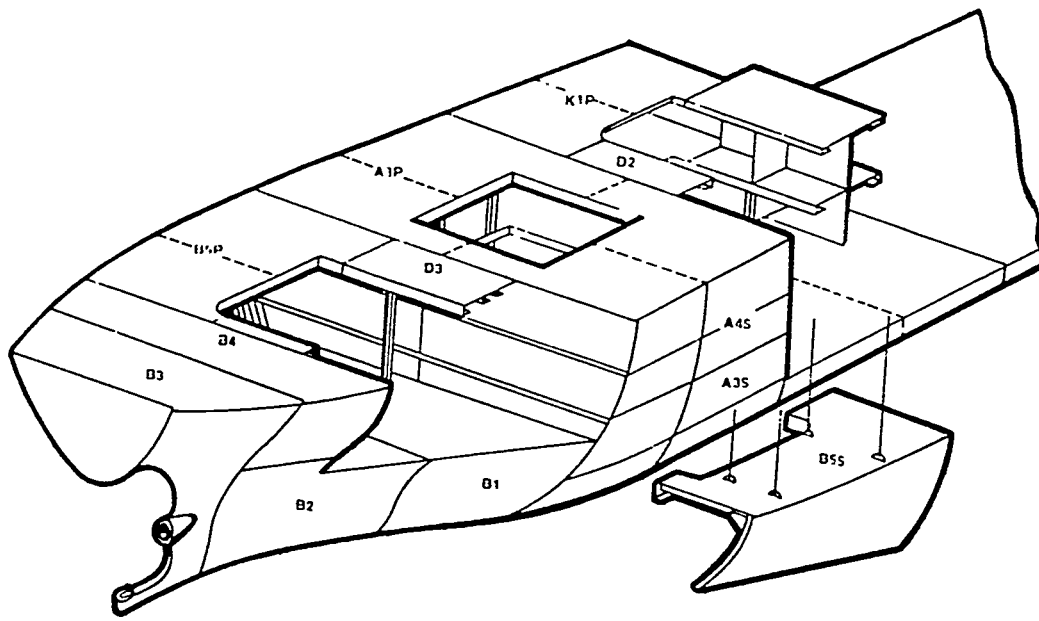
Unit or block butts are arranged so that the edges are accessible with a minimum of staging and the work is downhand where possible.

During erection, units may be lifted straight, rotated through 90 degrees or turned over. The ability of the craneage to carry out these operations depends on the type of cranes and the arrangement of hooks and lifting beams. The correct positioning of lifting eyes for these operations must be carefully calculated.

Fairing is done using various welded and non-welded aids, such as hydraulic push/pull cylinders which can clamp to the stiffening in order to bring the unit edges together. Fairing points are designed into the steelwork in conjunction with these aids. These devices avoid the traditional fairing logs which require welding, thus damaging the steelwork, and then grinding off and buffing smooth. Line heating can also be utilized to assist in structured alignment.

Excess material left on the unit edges until the construction stage is a commitment to rework, and is often minimized either by making allowances for shrinkage or by grinding the excess off before the unit is erected.

Optical devices and datums marked on the berth or dock are used to ensure accurate alignment of the units during erection.





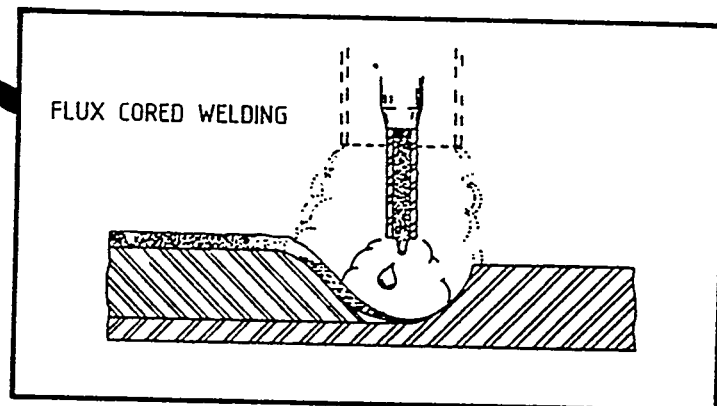
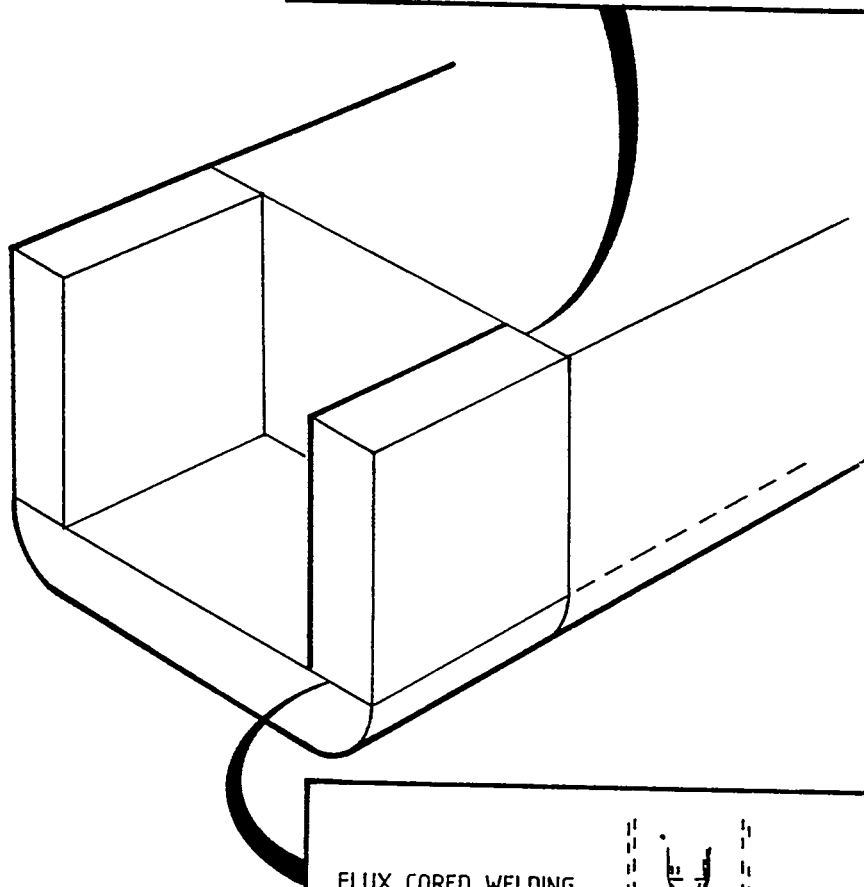
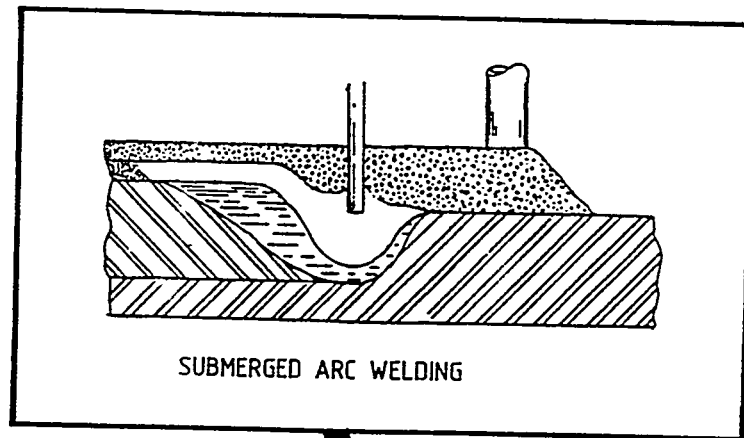
### 2.3.1.29 Welding

There are a large variety of welding processes available for use at the final construction stage and the choice depends upon the type of ship, level of investment and prevailing weather conditions.

Typical processes are:

Manual Metal Arc	- For structural connection
Electrogas Welding	- Main ship longitudinal butts
Submerged Arc Welding (using lightweight portable tractors)	- For overhead welding such as tie deck butts
Mechanized Vertical Welding (using a portable climbing tractor)	- For vertical shell butts
Electro Slag Consumable Nozzle Welding	- For butt welds
Flux Cored Welding	- Tiller and butt welds
Stud Welding	- Fairing, temporary attachments
Arc Air Gouging	- Used in two sided welding

The final construction stage provides with an electrical distribution system with a continuous array of outlets thus minimizing the length of cable runs and the associated weight.



### 2.3.1.30 On Board Services

Services required for construction activities are:

- Water
- Compressed air
- Oxygen
- Acetylene or other gas used for burning or cutting
- Electricity

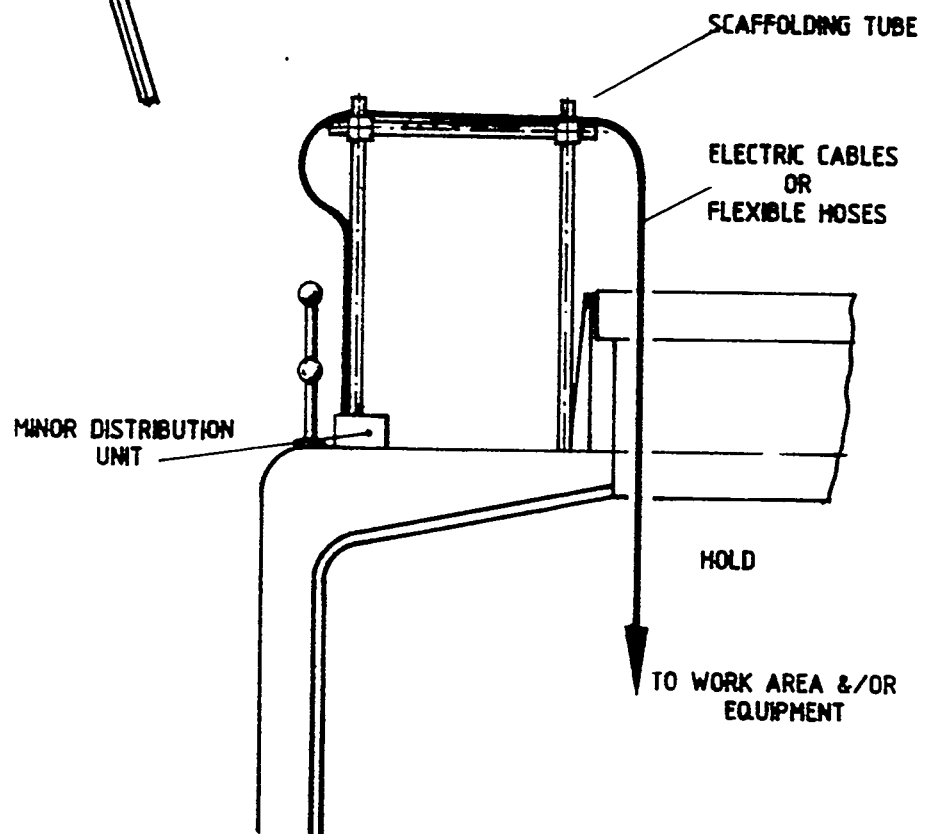
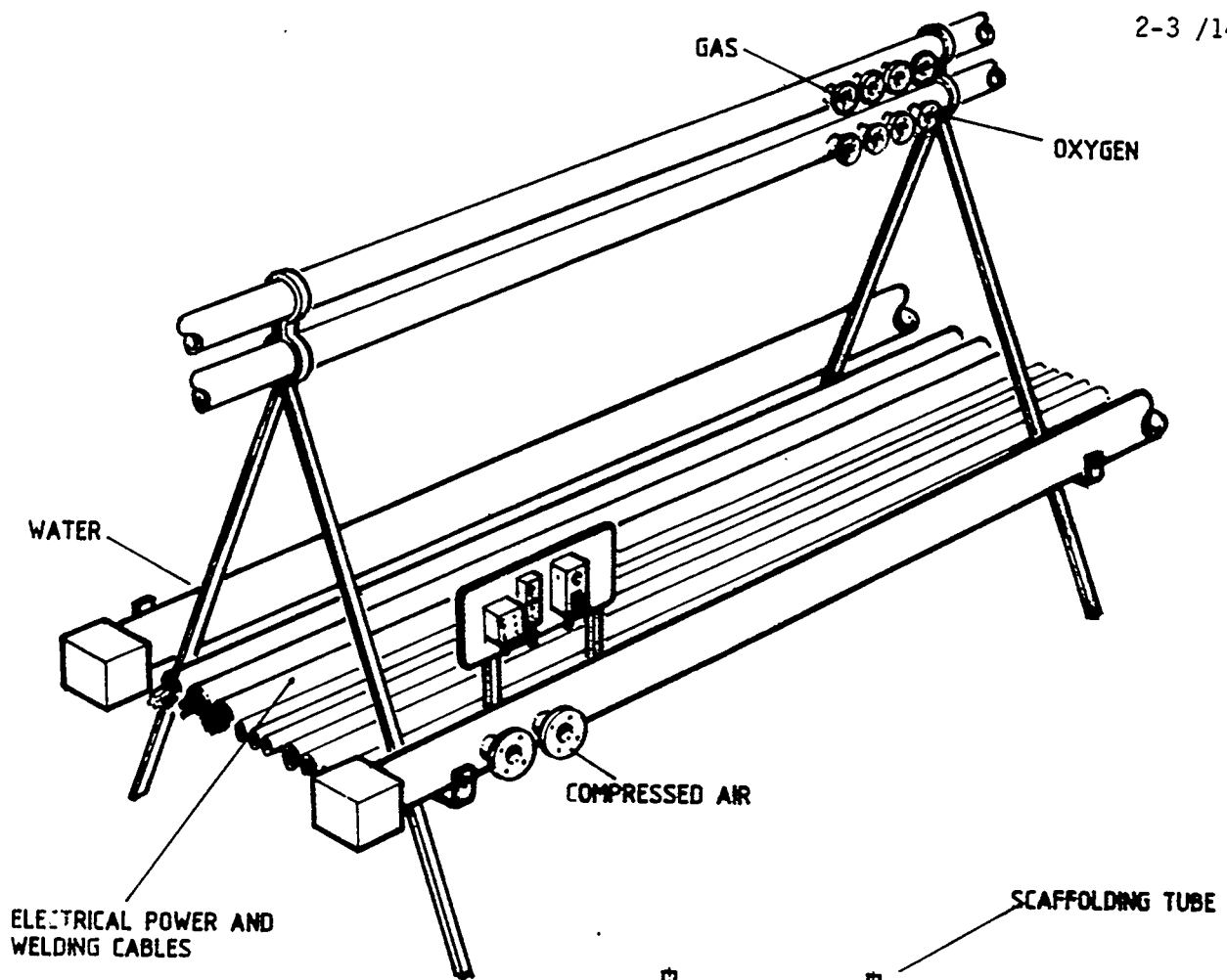
Traditional practice was to connect each item of plant or tool to the nearest outlet available at the point of use. This led to a mass of cables and pipes looped and criss-crossed to the various working areas.

Modern practice uses portable service outlet units, which consist of a framework onto which the various service pipes are attached. These units are quickly connected and positioned on board the ship and operators connect their equipment at the nearest outlet, thus reducing cable lengths with less entanglement and better safety.

Service runs can be designed as part of the ship's piping system particularly in the engine room. These provide services during construction and, if left on-site, may be used during later repair and servicing operations.

Electrical power is produced from alternators (or shore supply points) and the cables are then run from the main switchboard to sub-switchboards and distribution boards to which equipment is connected. The subswitchboards and distribution boards are located throughout the ship serving various areas such as:

- In the deck stores for lighting and power for tools.
- At engine room for the control and power for various services.
- On the upper deck for accommodation.
- Near the galley for galley equipment.



### 2.3.1.31 Staging and Access

Access to the ship is provided by gangways, stairway towers, escalators or elevators, leading to one or more levels on the ship. The requirements for access to the ship structure are minimized by:

- Completing work on units at earlier production stages.
- Painting before erection.
- Pre-erection outfitting.

To enable fairing and welding of unit joints and subsequent finishing off operations (such as touch-up painting) to take place it is necessary to provide access ways to these areas. Invariably this means providing staging to the various levels at which work must take place.

Traditional shipbuilding techniques made it necessary to surround the ship completely with a large amount of staging which require numerous welded attachments (and hence a lot of remedial work) to the ship plating. The approach to ship erection involving a "natural" breakdown of structure has the potential to substantially reduce the amount of staging equipment required. Special purposely designed shipbuilding stages can be used, further reducing the effort involved in this important but non value adding activity.

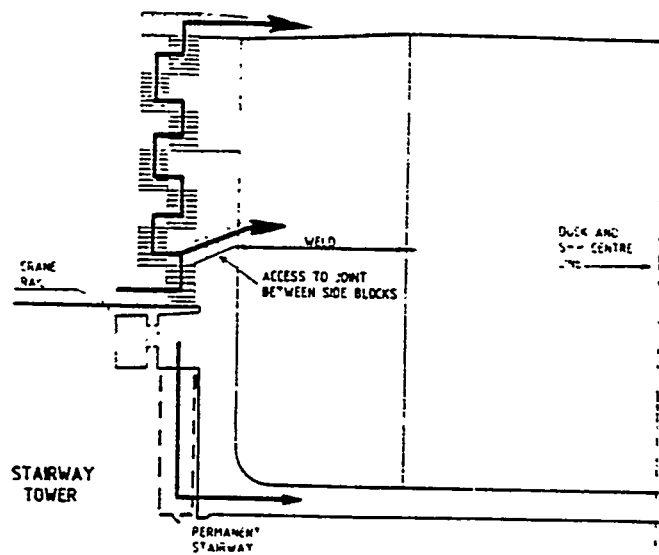
Commercial modular staging systems have the following characteristics:

- They require a minimum of welded attachments to the ship's hull.

- They are capable of rapid erection.

- They are capable of rapid dismantling and only require small access ways for removal from within the ship. (This is particularly important on tankers which have no large hatches).

Alternatively, the ship's own structure may be used as a working platform. Often, minor alterations to the ship's structure at the design stage can reduce staging requirements.



USE OF SHIP'S STRUCTURE FOR ACCESS

# STAGING AND ACCESS

### 2. 3. 1. 32 Pipework Installation

Pipework is installed by the following methods:

- As part of an outfit unit.
- As pipe assemblies (pipe banks).
- As individual pipes.

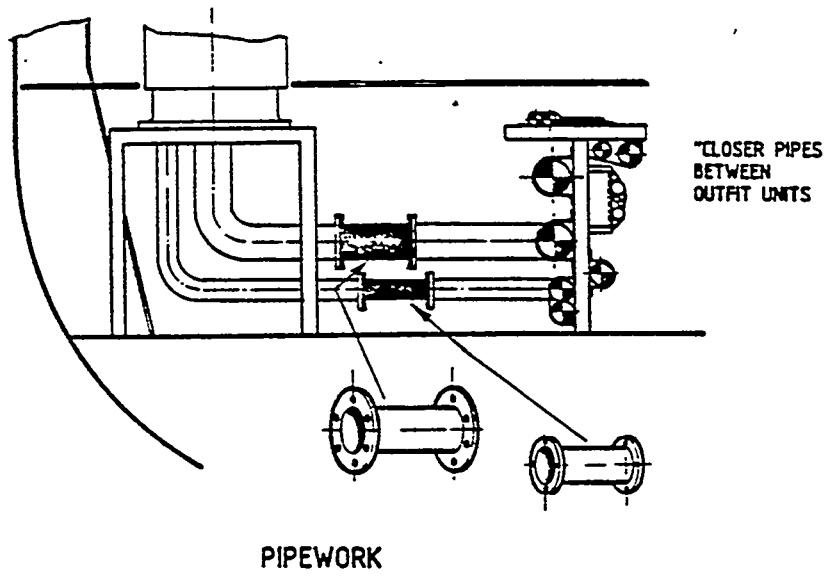
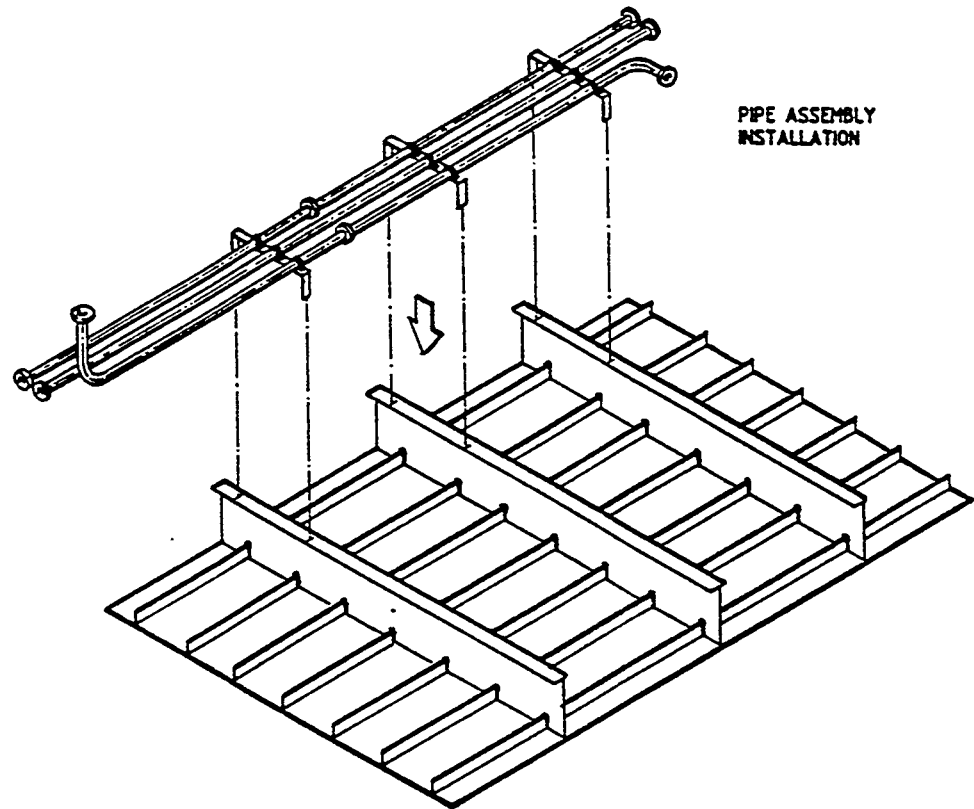
Installation may be either:

On unit or block before erection.

Open sky, after erection, before the compartment or zone is closed off by the block above, allowing cranes to drop the outfit unit or pipe assembly into position without obstruction.

Later in the erection period, with pipes being installed individually (traditional pipe outfitting).

The majority of pipes which are fitted individually are closing pieces which link pipes that have already been installed. These closing pieces effectively overcome problems of dimensional accuracy between blocks, as their exact shape and size are lifted once the steelwork is finished. The better the accuracy of steelwork construction, the fewer the numbers of closing piece pipes that are required.





### 2.3.1.33 Engine Room Machinery

The machinery to be installed in the engine room typically consists of :

- The main engine(s).
- Diesel generators/alternators.
- Shafting and bearings.
- Auxiliary machinery.
- Ballast/fire pumps.
- Cargo pumps.
- Other cargo machinery.

The main engine is installed late in the construction period, as once it is positioned, access in the engine room is poor. The engine may be installed in one piece if heavy lift cranes exist or in a number of parts. Resin chocking is used for engine alignment on the steel structure because it is less costly than using steel shims and chocks. In addition, the installation can be carried out prior to completion of all structural work.

The diesel generators are also commonly installed open sky in one lift per generator.

The shafting and bearings are installed relatively late in the build cycle and again resin chocking is now gaining acceptance for the alignment of both stern bearing and the thrust bearing. This avoids the need for a lengthy stern bearing boring period which may often be on the critical path of the vessel build cycle.

The majority of auxiliary machinery is installed in the form of outfit units which are dropped onto the tank top or ER flats when convenient. The quantity of connections to be made are relatively small as the majority of connections are arranged to be within outfit units and are thus already complete. Individual units are provided with adjustable feet so that they may be correctly positioned with a minimum of welding.

2.3.1.34 Hull Engineering

Hull engineering consists of the installation of such items as: -

- propeller shaft and bearings
- propeller
- rudder
- thrusters
- cranes
- hatches
- deck machinery

Lasers or theodolites are used for alignment of the shafting. Boring out of the bearings is normally done when the hull structure is well advanced, although more recently some yards are using resin chocking for the shaft bearings and are therefore able to bore out the rudder stock bearings before block erection.

### 2.3.1.35 Electrical Installation

Electrical installation work can be considered to be divided into installation of the cable runs and cable termination. Cables are routed along cable trays and, when routed through the ship's structure, pass through penetrations or bulkhead glands.

A certain amount of cables are installed on the outfit unit, while longer runs of cable are installed "on-board" during the ship construction stage. Cable runs are predefined during design and this allows the cable trays (particularly deckhead runs) to be installed before erection of the unit.

Where cables are partially installed the cable is coiled until the remaining cable can be pulled and completed. Some splicing of cables is now possible, allowing a greater degree of advanced installation of cables. Splicing is done by either sealing the joint with resin or by using heat shrinkable joints.

2.3.1.36 Sheet Metal Work & Joiner Work

Sheet metal work at the ship construction stage consists of the installation of:

- Ventilation trunking"
- Cabinets
- Insulation cladding

The majority of ventilation trunking is installed on outfit units or on the deckhead downhand before erection; on board work consist of installing the in-fill pieces between preinstalled venting, across unit butts. Ventilation routings are predefine at an early stage of design along with the pipe and cable runs.

Cabinets, etc., may be installed on "grounds" which are attached to the deck to ensure a flat horizontal surface onto which the cabinets are screwed.

Insulation cladding is installed on board late in the build period as the insulation is not fixed to the structure until local hot work is complete.

Joinerwork at the ship construction stage consists of:

- Installing prefabricated bulkheads.
- Installing furniture and fittings.
- Installing false ceilings.
- Fitting grounds.

Much of the traditional joinery function has now been superseded by the increasing use of prefabricated fittings, furniture or complete cabin assemblies.

#### 2.3.1.37 Final Painting

The final coat or coats of paint are applied shortly before trials and delivery in order that the appearance of the ship is good.

Internally, touching-up with brushes or rollers and final spraying of tanks is done and externally the final exterior hull coating is applied with spray guns.

The exterior types of paint, particularly those used below the waterline, such as self-polishing paints, are how very specialized and the application of these paints is a relatively skilled job.

Paint application should only be carried out when good atmospheric conditions are prevailing. Painting is ideally carried out.

When the air temperature is above the lower drying or curing limit of the coating.

When the surface is dry, without condensation.

When the surface is at least 3 degrees above the dew point.

In dust-free conditions.

#### 2.3.1.38 Testing and Commissioning

All mechanical and electrical systems are tested and commissioned before delivery of the ship to the owner.

Systems which are tested will include:

Engine Room Systems:

- Main engine/propulsion/performance
- Auxiliary machinery
- Pumping systems

Deck Systems:

- Cranes
- Hatches
- Moorings gear

Accommodation

Lighting

Alarms

Rescue/Safety Systems.

A test and commissioning program is used to define at what stage testing is carried out and allows as much integration of testing into the construction program as possible. This reduces the time between launch and delivery.

The ship's main engine propulsion system and performance is tested after launch during sea trials, during which the speed/power curve for the ship is determined along with other trials such as maneuvering, stopping and mooring. Rescue and safety systems are also tested and commissioned such as the operation of the lifeboats and fire and wash lines.

Any defects found during the testing program are noted and repairs carried out where necessary, after discussions with the owner's representatives and regulatory bodies.

#### 2.3.1.39 After Launch/Float-Out

After launch the main activities are:

Testing of those systems which can only be tested when the vessel is afloat.

Final outfitting at an outfit quay.

Sea trials.

Repairs to defects.

Yards which have heavy lift cranes available over the outfit quay such as a floating crane, may install the main engine and accommodation block after launch. An overall shortening of the build cycle results as the accommodation can be assembled and outfitted in parallel with the hull construction. Other heavy items, such as large hatch covers and deck cranes may also be installed after launch or float-out.

#### 2.3.1.40 Layout and Material Flow

An important factor influencing the efficiency of the shipyard is a logical and well planned material flow. The flow should be unidirectional as far as possible and flexible enough so as not to be unduly disrupted by any necessary variation in the production sequence. Unidirectional does not necessarily mean a straight line movement but does imply a well defined one way flow. The handling of material against the general flow should be avoided as this jeopardizes smooth operation.

From a design viewpoint, it is important to know of any restrictions imposed by the layout. The capacity of the materials handling equipment from process to process is also important. Necessary information should be included in the documentation provided to the designer (see Chapter 2.3.2).

In the more productive shipyards the layouts are well defined, with workshops and construction facilities generally laid out to suit the production requirements and with material flow unidirectional, except where site constraints prevail.

Generally the steel flow and handling method is as follows.

From	(Process)	To	By
Stockyard	Storage	Treatment	Conveyors/Magnet Crane
Treatment	Cleaning/Painting	Preparation	Conveyor/Self Elevating Transporter
Preparation Shop	Cutting & Forming	Minor Assembly Area	Magnet Crane



From	(Process)	To	By
Minor Assembly Area	Part Joining	Assembly	Hook Crane/Fork Lift Truck
Assembly Shop	Sub-assembly and Unit Assembly	Outside Storage/Block Assembly	hook Cranes in the shop Elevating Transporter outside
Block Assembly Area	Erection	Dock/Berth Side	Self Elevating Transporter Construction Cranes

For outfit the flow and handling method is typically:

From	(Process)	To	By
Warehouse	Storage	Manufacturing Shop	Fork Lift Truck
Palletizing Area	Palletizing and Collection	Assembly Area	Hook Crane/By Hand Fork Lift
Assembly	Assembly Installation	Installation	Hook Crane/Fork Lift Truck wheel ed Transporter

#### 2.3.1.41 Material Handling

A large proportion of total manhours is associated with searching for, moving, positioning and handling steel and outfit materials, components, subassemblies and assemblies. In those shipyards which have neglected advances in handling and storage methods, up to sixty per cent of total manhours may be spent on these activities.

Productive shipyards concentrate on purpose designed handling and transportation systems, and pallet systems are widely used. Highly developed and successful materials handling is an indication of a high level of organization.

#### Cranes

Cranes have two functions in shipbuilding: as an aid to production and a means of moving material. The first should be their primary function, because more economic means of moving materials are usually available. From the design viewpoint, the important information about any crane is the limits of its capability. These include its lifting capacity, its lifting height, its turnover capability and the limits of travel. This information helps to define the interim products which can be produced and moved about a shipyard.

For movement of materials, as opposed to manipulation, vehicles or conveyors are preferred.

#### Conveyors

Unlike volume production industries, conveyors are unusual in shipyards except in some specialized areas. The most common applications are steel treatment lines, panel lines, pipe manufacture and shape cutting.

Conveyor systems provide fixed material flow paths and their capacity defines the maximum and minimum sizes of products which can be handled.

Vehicles provide a more flexible and lower cost solution to shipyard materials handling. Some are conventional, others have been developed specifically for shipyard applications.

#### Fork Lift Trucks

Fork lift vehicles are extremely versatile and flexible in operation. In order to maintain control, it is essential to have a good materials organization. The most effective use of fork lift vehicles is made when small pipe piece parts and components are palletized. Both front fork and side loading vehicles can be used.

#### Straddle Carriers

Some shipyards have adopted straddle carriers for handling of plates in the steel stockyard. With the use of special cradles, they can also handle steel shapes and pipes. Although expensive, they can replace fixed gantry cranes. Where there is no space restriction, they can give a lower cost stockyard.

#### Self-elevating Transporters

These vehicles are used extensively in shipyards to move assemblies, units and blocks. Their major advantage is that the self-elevating platform allows the vehicle to load and unload independently of cranage. The steel unit is supported on trestles or stools about six feet above the ground, allowing the vehicle to drive underneath. The capacity of a self-elevating transporter may determine the maximum block weight and dimensions in a shipyard.

This type of vehicle supersedes a tractor-trailer unit.

Smaller vehicles of the same type can be used for movement of steel plates and shapes.

### 2.3.2 GUIDELINES FOR FACILITY CAPABILITY DOCUMENTATION

This chapter describes what information should be documented by shipyards, for the use of designers and production engineers. The design stage at which the various sets of information are needed is described. There must be awareness of facility capability at a high level of overall planning and early design and at a detailed level for later stages of design and planning. A hierarchy of facility information is developed. A set of document formats for the presentation of the information has been developed and is included in the chapter.

#### CROSS-REFERENCES

2.1.6 Impact of Facilities on Design

2.1.7 Need to Document Facility Capability and Constraints

### 2.3.2.1 Introduction

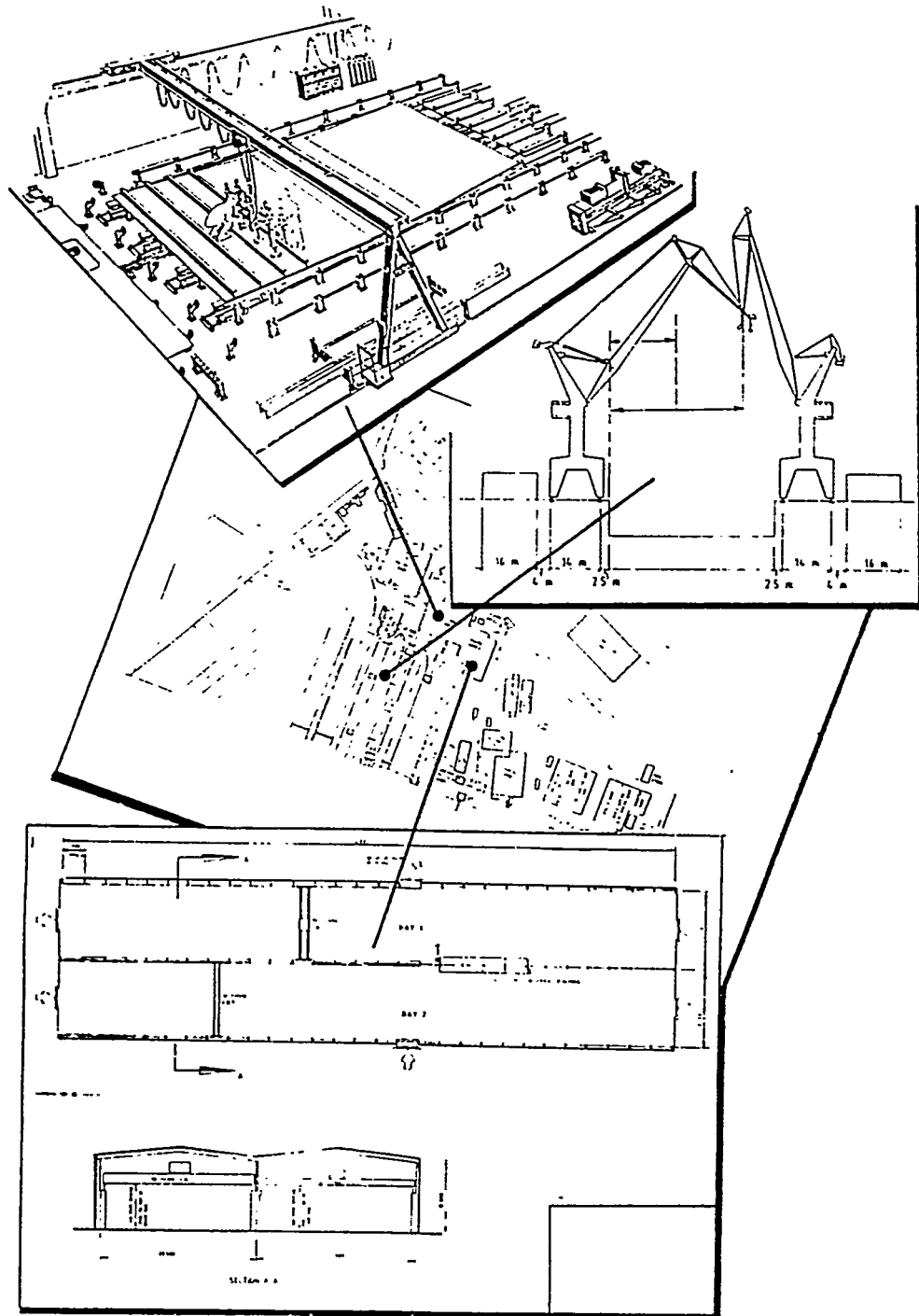
In order to make an assessment of its own capacity and capability, a shipyard must be aware of its facilities. This awareness can be at a high level in terms of overall tonnage or at a very detailed level as in the specification of equipment at a particular work station.

Information on the capacity and capability of the shipyard is needed for various purposes:

- Process Analysis
- Production Engineering
- Scheduling
- Planning
- Estimating

This chapter presupposes that the shipyard has documented its facilities. It is therefore intended to consider which information is required at a given design stage, and to define a format for transmitting that information to the designer.

The information so provided must be tailored to the particular design need. Given too much or too little information on the facility, the designer is unlikely to take it into account.



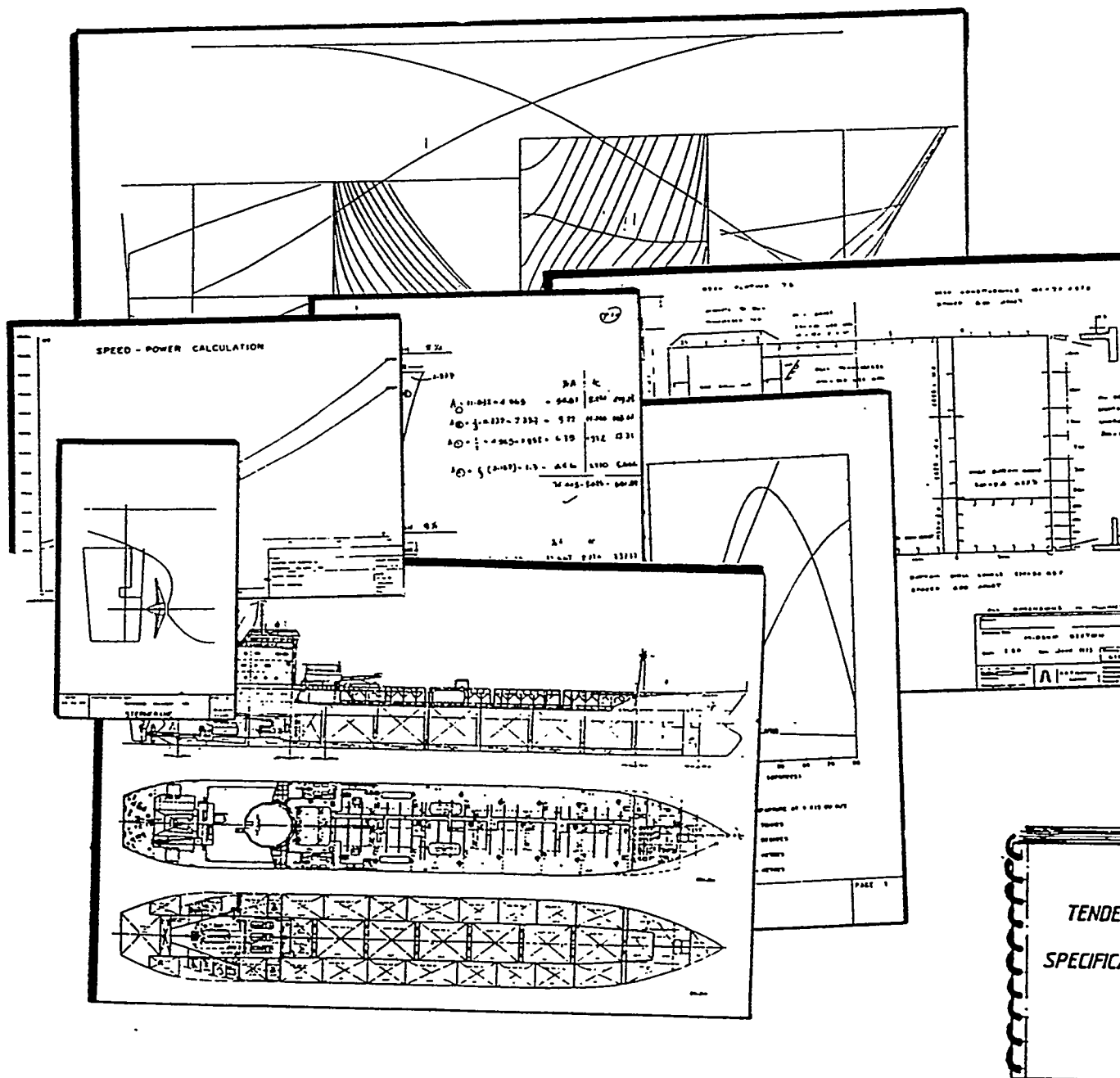
# FACILITY CAPABILITY DOCUMENTATION

#### 2.3.2.2 Conceptual Design

This stage of design establishes the overall features of a design, to satisfy an owner's functional requirements. The output of this design stage is shown opposite and include:

- Preliminary General Arrangement
- Preliminary Midship Section
- Preliminary Specification
- Preliminary Calculations (Dimensions/Capacities, etc)
- Preliminary Body Plan

If a shipbuilder has been identified, then production input should be provided. The overall objectives at this stage are to ensure that the design is compatible with the shipyard facilities. At its simplest the question is whether the proposed vessel will fit into the shipyard dock or other construction facility. In more detail it is possible to reduce the potential work content of the vessel from the earliest stage.



## CONCEPTUAL DESIGN OUTPUTS



Inputs to the conceptual design are as follows:

#### Shipbuilding Policy

- a) Range of Ship Types and Sizes - Most shipyards have a defined product mix and throughput requirement to meet long term goals.
- b) Tonnage Throughput - This gives a broad assessment of the capacity of the yard and will give the designer a rough guide as to the construction time.

#### Overall Definition of the facilities

- a) Building Dock/Berth Sizes and the Maximum Ground Loads - The construction site offers the main constraint on what the yard can build. Allowable ground loadings may be relevant and where a floating dock or ship lift is used the maximum weight distribution must be known.
- b) Medium Ship Size for Multiple Stage Construction - For series production, multiple stage construction methods may limit the ship dimensions, if, for example, two ships are built side by side at the same time in one dock, or if the stern portion is built behind the complete hull of the previous vessel (semi-tandem construction).

#### Production Influenced Design Standards

- a) Standard Frame Spacing - Although frame spacing could be considered as a design standard, once the standard is established production will become geared to it by the creation of jigs, for example, and thus it can also be seen as a facility capability. Changing the frame spacing will reduce the efficiency of production. Modular spacing which is related to material sizes can reduce material costs and scrap losses.

SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE


BUILDING DOCKS
----------------

DOCK	LENGTH	BREADTH	DEPTH	FLOAT OUT DRAFT
1	450 ft	150 ft	35 ft	25 ft
2	300 ft	100 ft	25 ft	18 ft


INTERMEDIATE GATE POSITIONS

DOCK	DISTANCE FROM GATE	
1	300 ft	120 ft
2	200 ft	90 ft

COMMENTS :



No 1



No 2

SCALE 1 .

- b) Preferred Frame Spacing - Where it is not possible to have a standard frame spacing a preferred spacing or range of spacings is required.

Frame spacing may vary from one zone of a ship to another, for example, the fore end spacing may be less than the cargo hold frame spacing. Within any one zone the spacing should be constant.

#### Material Size

- a) Maximum Plate Length and Breadth - These dimensions have a particular impact on block definition, Size and conerol arrangement of the vessel.
- b) Maximum Shape Size - Any limitations should be known by the desigrer and where possible taken into account. It is better from a production perspective to use avilable material rather than make shapes specially.
- c) **There may be several standards geared to particular process lanes. For example, plate lengths may be selected to suit:**
  - curved panel capability
  - flat panel capability
  - internal structures

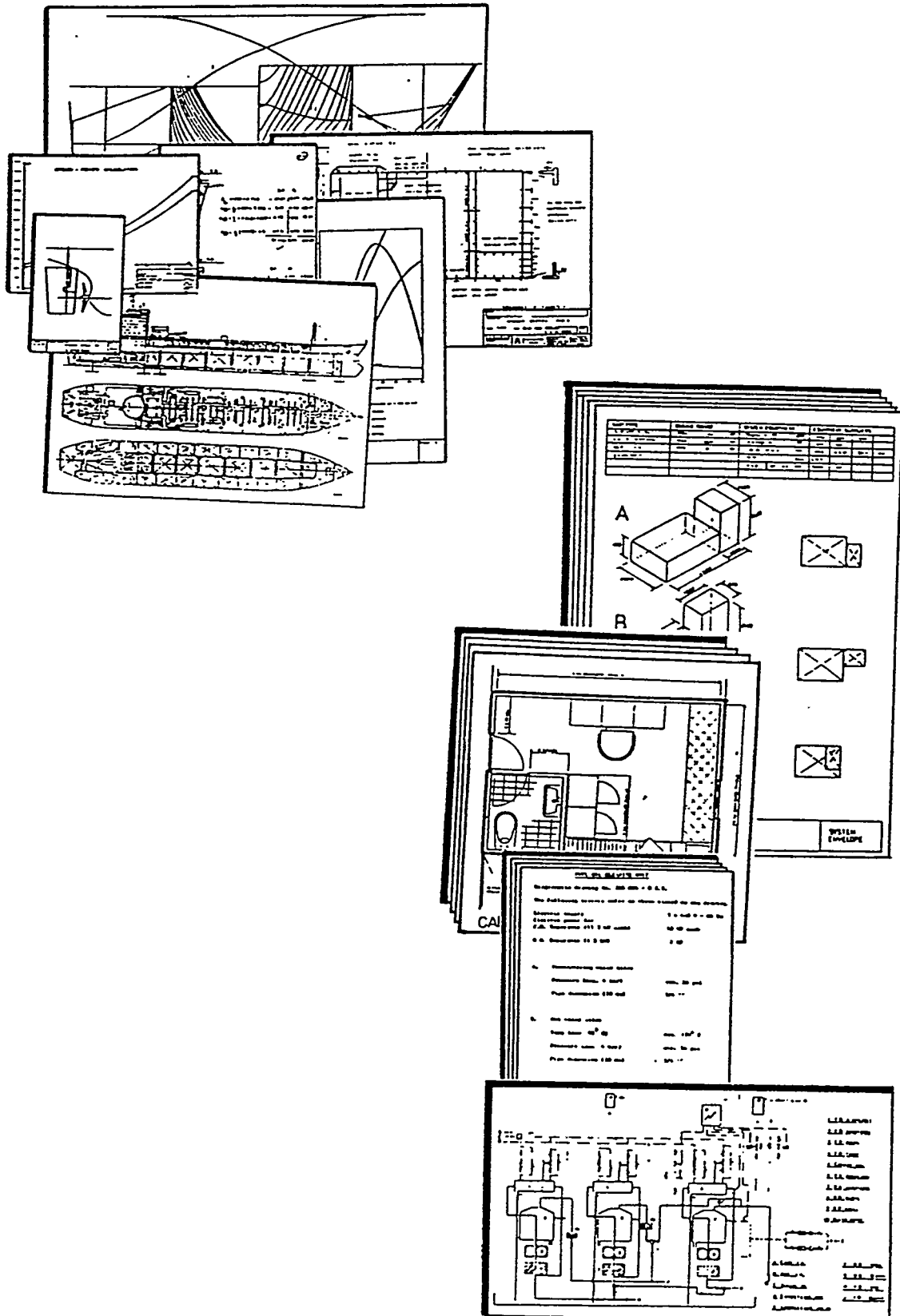


### 2.3.2.3 Contract Design

Contract design establishes the features of a design sufficient to provide the basis of a contractual arrangement. The designer must have more information of the yard constraints, material sizes and design arrangements with which production are familiar in order to complete the preliminary design stage for the vessel. The design outputs of this stage are as follows:

- General Arrangement
- Midship Section
- Specification
- Approximate Ship Calculations, for example:
  - Hydrostatics
  - Freeboard
  - Stability and Trim
- Resistance and Propulsion Calculations
- Engine Capacity
- Engine Room Arrangement
- Accommodation Arrangement
- Piping Diagrams
- Electrical Load Analysis

Production outputs are summarized in a preliminary build strategy.



CONTRACT DESIGN

Inputs to the contract design are as follows:

#### Maximum Assembly Sizes and Weights

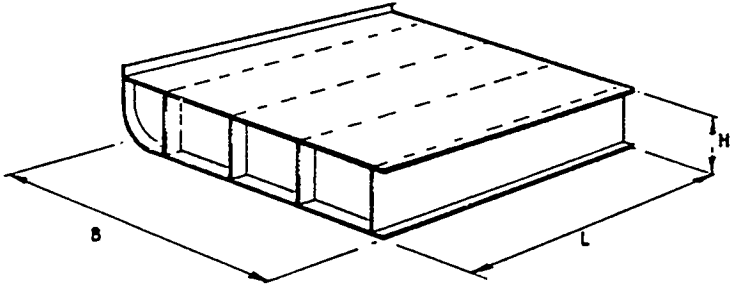
- a) Block Size and Weight - Generally defined from the crane capacity, transporter capacity and shop door sizes. The block breakdown, produced at this stage of the design process, is influenced by the maximum block sizes and weights.
- b) Steel Unit Size and Weight - Generally defined from the shop crane, shop floor area and Transporter capacity.
- c) Panel Size and Weights - In the case of flat panels the maximum size may be defined either by the panel line capacity or shop floor areas and crane. For curved panels the maximum size is defined by crane/transportation and jig areas.
- d) Subassemblies - The basic characteristics of process lanes should be available to the designer to enhance standardization.

#### Raw Material Size and Weight

- a) Standard Plate Size and Weight - In order to produce the midship section and final general arrangement the designer must be aware of the standard plate size/sizes used in the shipyard. There may be a range of breadths and lengths and a number of thicknesses.
- b) Standard Shape Types and Sizes - As above, the shapes with which the designer may work must be known. Standard shape length is equal to plate length.
- c) Standard Preferred Pipe Lengths - On the outfit side pipe lengths must be known when producing the piping diagrams. Later, during the functional design stage, more information on pipework and other outfit components is required.

SHIPYARD NAME	DWAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE

<b>MAXIMUM ASSEMBLY SIZE AND WEIGHT</b>
---

	NAME : Double Bottom Unit	CODE DB
		
	<p><b>MAXIMUM SIZE</b></p> <p>L = 28 ft</p> <p>B = 22 ft</p> <p>H = 7 ft 6</p> <p><b>COMMENTS :</b> B limited by Assembly Shop door width L limited by maximum plate length</p>	
	<p><b>MAXIMUM WEIGHT</b></p> <p>Leaving Shop = 35 t</p> <p>At Erection = 70 t</p> <p><b>COMMENTS :</b> Transporter capacity out of shop = 35 t Erection craneage = 75 t</p>	
	SEE ALSO	<p>Process Analysis Unit Type      Code</p> <p>Unit Assembly Work Station      Code</p>



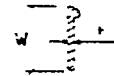
SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION		REV	DATE

### RAW MATERIAL SIZES - SHAPES

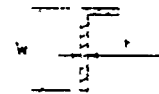
STANDARD LENGTH = 25 ft

#### TYPES AND SIZES

TYPE	W	t
Offset Bulb	2.7 ins	0.25, 0.37
Pipe	2.5 ins	- , -
-	-	- , -
-	-	- , -



Offset Angle



"I" Section



Square Section



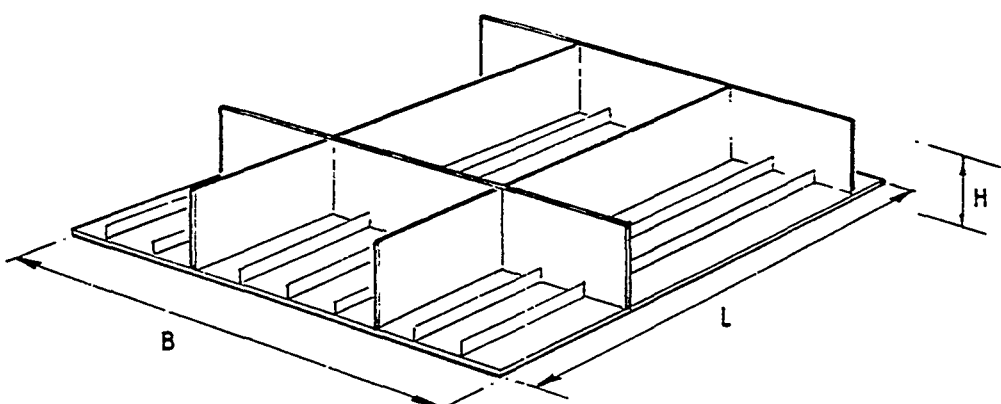
Flat Bar



SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE

MAXIMUM ASSEMBLY SIZE AND WEIGHT
----------------------------------

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<p>NAME : Flat Panel Assembly</p> <p>CODE FP</p> 
<p>MAXIMUM SIZE</p> <p>L - 28 ft</p> <p>B - 15 ft 3</p> <p>H - 7 ft 6</p> <p>COMMENTS : L limited by shop door width H limited by available standard plate width</p>
<p>MAXIMUM WEIGHT</p> <p>Straight Lift = 19.5 t</p> <p>Turnover Lift = 9.5 t</p> <p>COMMENTS : Shop Cranage = 2 x 10 t</p>

### Hull Shape

- a) Bilge Radius - Production jigs and/or the shell rolls capability will define or limit the bilge radius.
- b) Camber and Sheer Standards - Again, the presence of jigs on the shop floor may limit the designer to using standard or preferred camber, sheer and rise of floor, etc.

### Spatial Analysis

- a) Preferred Engine Room Layout - Production may well be used to particular engine room layouts, for example, having the control room say on the second flat on the port side forward. The designer must be aware of any preferred arrangements.
- b) Preferred Accommodation Layout - The obvious case of standard layout is having the bridge at the forward end of the upper level of the accommodation. The same principle may be applied to the position of the cabins, offices, mess rooms and galley, etc.

### Outfit Units

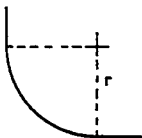
- a) Outfit Units Arrangements - As above, standard arrangements of outfit units with respect to each other and the steel hull must be known.
- b) Maximum Size and Weight of Outfit Units - The maximum size and weight of these units will be limited by craneage, transporter capacity and shop size. The designer must be aware of how large these units can be and also if they will be installed on-block or on-board. If it is the former case then the weight of the outfit units on the block must be taken into account when considering the- block size and weight.

SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE

HULL SHAPE

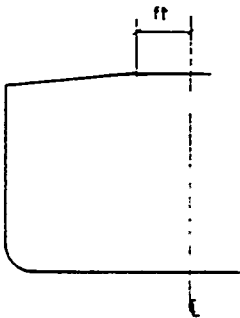
BILGE RADIUS

Range r = 3 ft to 5 ft



COMMENTS : Preferred Radius 4 ft to suit production jigs

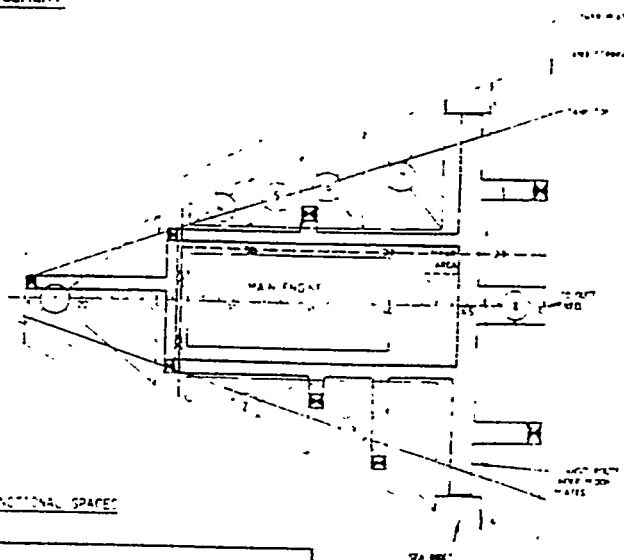
CAMBER		RANGE / PREFERRED VAUE
AFT END	straight line	1 : 25
CARGO HOLD	" "	1 : 25
FORE END	" "	1 : 25
SHEER		
AFT END		
FORE END	straight line	no limit
CARGO	none	1 : 25



SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE

SPATIAL ANALYSIS - ENGINE ROOM

### TANK TOP ARRANGEMENT



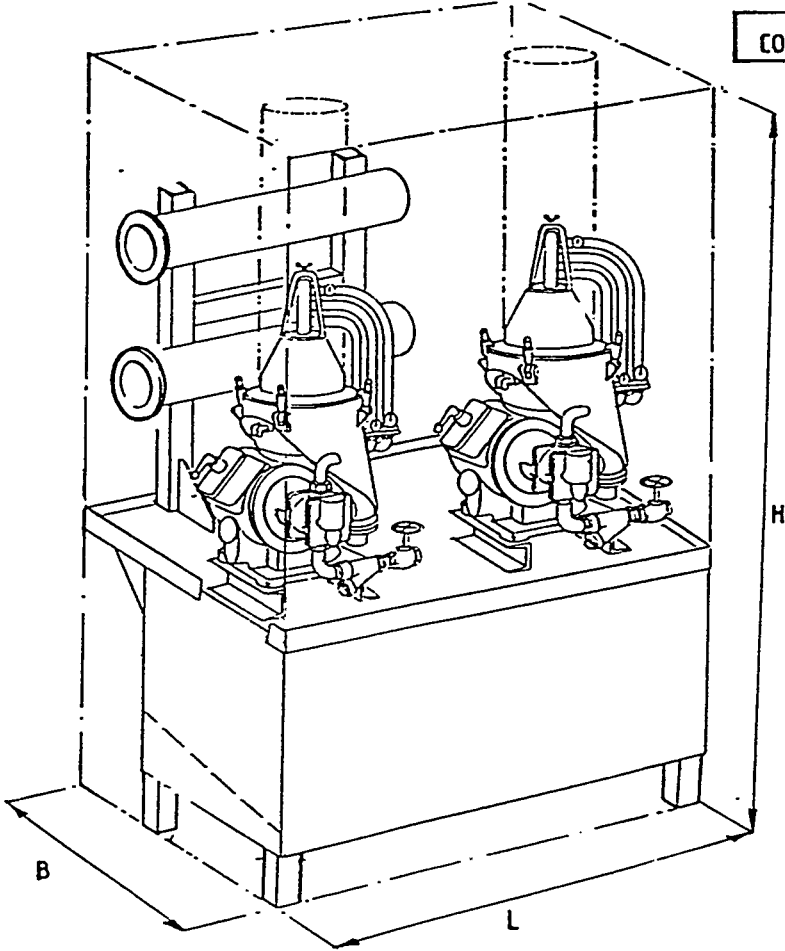
ENGINE ROOM - NATIONAL SPARE

Function	Location
1	<p><u>Power Plant Level</u></p> <p>Main Engine Lubrication Oil Pumps Shafting and Plummer Blocks</p>
2	<p>Boiler Feed Pumps Hotwell Feed Water Tank Auxiliary Condenser Lubrication Oil Transfer Pump</p>
3	<p>Main Sea Water Pumps FW Evaporator Ejector Pump Domestic Refrigeration Sea Water Pump Air Conditioning Sea Water Pump</p>
4	<p>Stuffing Box Drain Tanks Stuffing Box Drains Pump Stuffing Box Drains Fine Filter Scavenge Box Drain Tank</p>
5	<p>Camshaft Lubrication Oil Pump Camshaft Lubrication Oil Cooler Camshaft Lubrication Oil Tank</p>
6	<p>Sea Water Separator Sea Water Pump</p>
7	<p>General Service/Drain Pump Main Drain Pump Sea Pumps</p>
8	<p>Ballast Pumps Fresh Water Pump Fresh Water Transfer Pumps</p>

SHIPYARD NAME	CHAP	SECTION	SHEET No
PRODUCTION METHODS & PROCESSES			REV DATE

OUTFIT UNIT SIZE AND WEIGHT
-----------------------------

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	 <div data-bbox="1036 352 1408 407" style="border: 1px solid black; padding: 2px; display: inline-block;">CODE</div>	
	NAME	
	<div> <div>MAXIMUM SIZE</div> <div> <div>L =      ft    ins</div> <div>B =      ft    ins</div> <div>H =      ft    ins</div> </div> </div> <div>COMMENTS</div>	
	<div>MAXIMUM WEIGHT</div> <div>COMMENTS</div>	

### Service Runs

- a) Service runs in the engine room, accommodation and hull are defined at this stage of design, and any production preferred routes must be known.

Some typical routes in the engine room are:

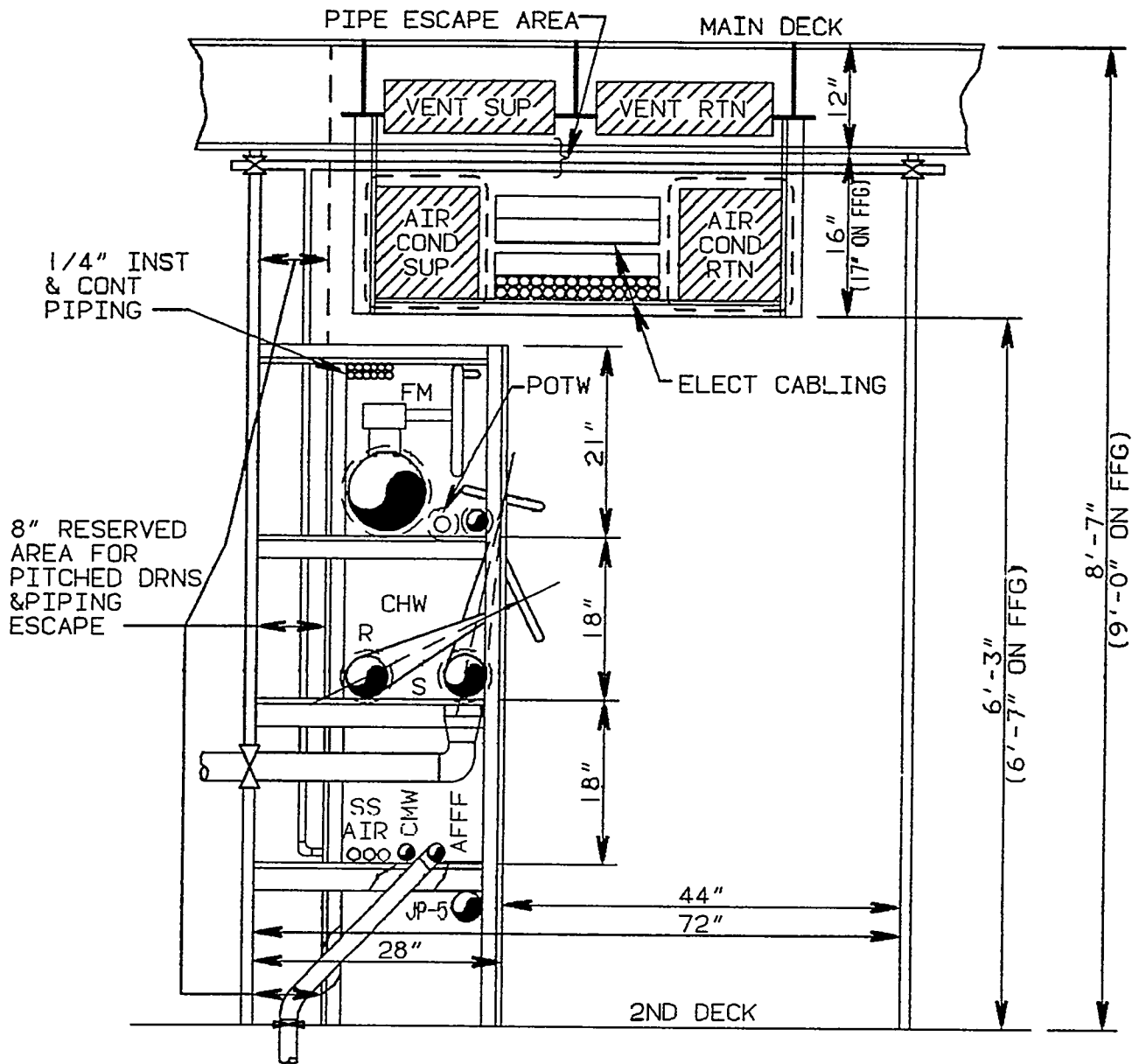
Forward and aft either side of the main engine.

Athwartships at the forward end of the engine room in line with the sea chests.

Vertical up the forward bulkhead.

- b) The design must address priorities of one type of service over another and over arrangements and structure. Typical priorities are expressed as cross sections through the service run and plan views. Typical priorities might be:

1. Removability routes
2. Waveguides
- 3.** Message tubes
- 4.** Ventilation and aspiration
5. Escape routes
6. Access routes
7. Operator platforms
8. Main cableways
9. Lighting, etc.



SECTION  
SERVICE DISTRIBUTION TRUNK & PASSAGEWAY



#### 2.3.2.4 Functional Design

Functional design follows contract signing and establishes features of the design for classification and owner's approval and material specification.

The steel design is developed and is produced for the complete ship from the midship section in sufficient detail to satisfy the relevant classification society. The designer must have knowledge of the steel interim products for the shipyard and other steelwork standards, such as bracket types and connection arrangements.

The development of outfit design for the engine room, accommodation and hull requires information on the standard outfit interim products and the standard outfit parts such as pipe sizes and flange diameters.

The design output at the contract design stage includes:

Ship Design:      Final Hull Form  
                            Final Ship Calculations

Structural Design: Approval Drawings  
                            Scantling Plans

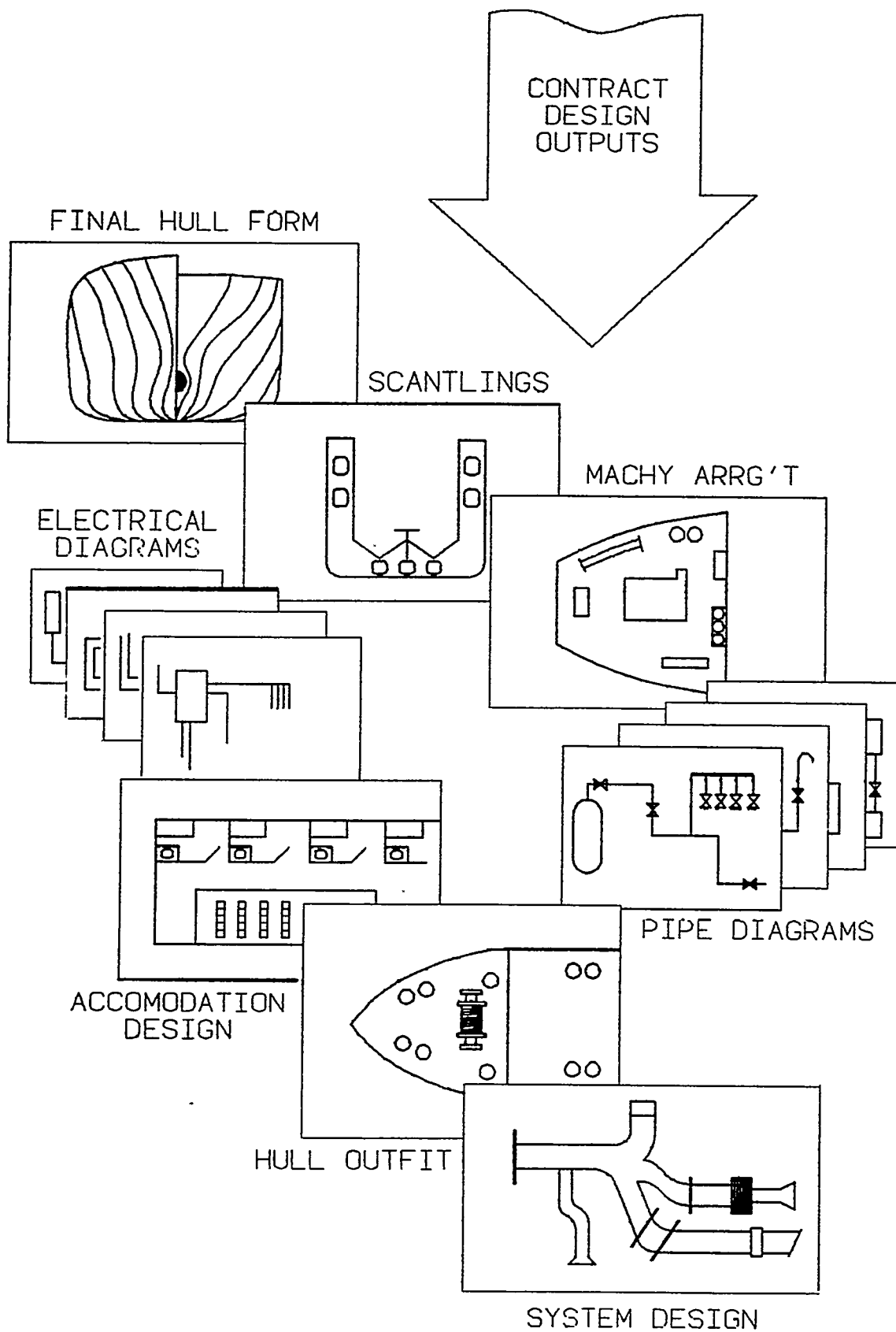
Machinery Installation: Final ER Arrangement  
                                    Piping Diagrams  
                                    Electrical Diagrams

Accommodation Design

Ship Systems Design

Hull Outfit

The production output is a contract build strategy, which is subsequently developed into schedules for all stages of production.



Inputs to the functional design stage are as follows:

#### Steel Interim Products and Related Work Stations

- a) Definition - Each interim product must be defined in terms of type, manufacturing process, size and weight. When producing drawings for regulatory approval the designer must ensure that each interim product that is created can be classified under one of the standard types.
- b) Manufacturing Location - Each interim product has associated with it one or more work stations.

The designer must be aware of any other limitations of the interim products defined by the work station location.

#### Outfit Interim Products and Related Work Stations

As above, the designer needs information on the shipyard outfit interim products, such as outfit assemblies, and the stages of production at which the interim products are installed on the steelwork.

#### Structural Details

- a) Spacing of Transverse and Longitudinal Material - Certain spacings in certain areas of the vessel may be preferred by production.
- b) Brackets - Brackets up to a certain size and thickness, may be flanged, defined by the flanging machine capacity, after which the bracket has a welded face plate.
- c) Connections - Production preferred connections, such as lapped stiffener/bracket connections.

SHIPYARD NAME		CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV	DATE
WORKSTATION CAPABILITY				
NAME Plate Joining		SHEET 5 OF 5		
CODE PJ01				
<p><b>MACHINE FUNCTIONS AND LIMITS</b></p> <p><b>MACHINE IDENTITY</b> <span style="float: right;">CODE</span></p> <p>Welding Machine    - Maximum plate length    = 25 ft                                     - Maximum plate thickness = 1.5 ins</p>				
<b>SKILLS REQUIRED</b>				
<b>TRADE</b>		<b>SKILL</b>		
Plater		Read work station drawings Set up plates as defined by drawings Tack plates using mma Check and record dimensions		
Welder		Operate welding machine Check for quality Check and record dimensions of panel		
<b>SERVICES</b>				
WELDING POWER				
COMPRESSED AIR				
WATER				
GAS				

SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE

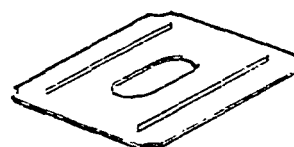
### STEEL INTERIM PRODUCTS

#### MINOR ASSEMBLY - CURVED PANEL ASSEMBLY

TYPE-  
WORKSTATION-  
CODE-  
DESCRIPTION-

Minor Assembly

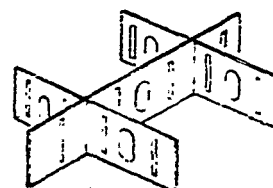
One plate piece part with one  
or more shape piece parts



TYPE-  
WORKSTATION-  
CODE-  
DESCRIPTION-

Sub Assembly

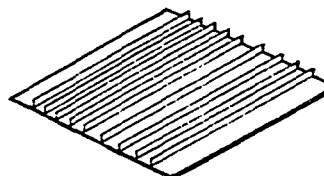
Two or more minor assemblies  
joined together



TYPE-  
WORKSTATION-  
CODE-  
DESCRIPTION-

Flat Panel Assembly

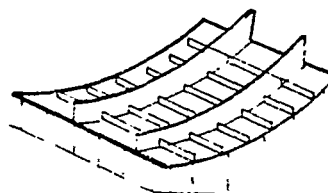
A single plate or number of  
plates joined and stiffened



TYPE-  
WORKSTATION-  
CODE-  
DESCRIPTION-

Curved Panel Assembly

A single curved plate or number  
of plates joined and stiffened  
with shapes, minor assemblies  
and/or sub assemblies

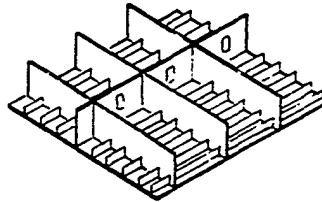


SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE

### STEEL INTERIM PRODUCTS

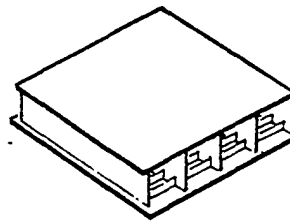
TYPE- Major Sub Assembly  
WORKSTATION-  
CODE-  
DESCRIPTION-

Consists of flat panels, curved panels, or other assemblies and parts joined together



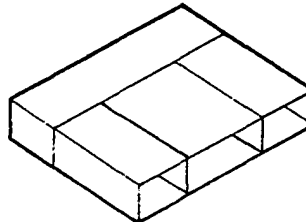
TYPE- Sub Unit Assembly  
WORKSTATION-  
CODE-  
DESCRIPTION-

Consists of a major sub assembly together with a flat or curved panel



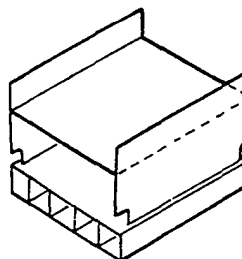
TYPE- Unit Assembly  
WORKSTATION-  
CODE-  
DESCRIPTION-

Normally consists of a number of sub-units joined together



TYPE- Block Assembly  
WORKSTATION-  
CODE-  
DESCRIPTION-

Normally consists of a unit together with another unit or major sub assembly



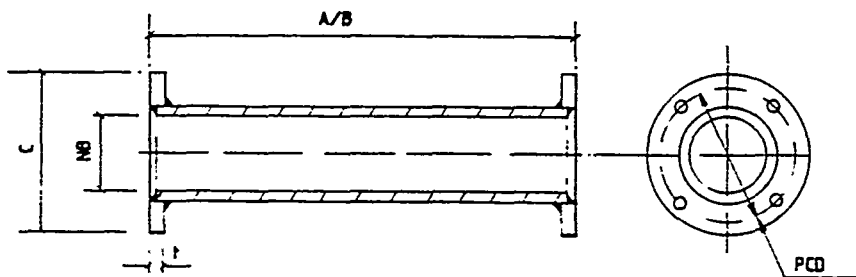
Pipe Information

- a) Pipe Sizes - At this stage of design pipe sizes may be identified and therefore the designer must be aware of the yard standards.
- b) Pipe Length - Pipe flanges and connections may also be identified at this stage and therefore standard pipe length data is required.
- c) Flange Size - Standard flange sizes for different pipe sizes are required to enable checks on clearances, etc, to be made when defining the contents of the service routes, such as the numbers and types of pipe running along one route. Information on the flange sizes is also required when defining the interfaces between outfit assemblies.
- d) Standard connections - Preferred connections should be specified to the designer.

SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE

### PIPE BORE , FLANGE AND LENGTH STANDARDS

#### STRAIGHT PIPE



STANDARD No	TUBE				FLANGES			LENGTH		
	NB	O/D			C	D	t	A	B	
	50	60.3	3000	1000	150		19			
	60	73.0	3000	1000	178		22			
	75	88.9	3000	1000	191		24			
	100	114.9	3000	1000	229		24			
	150	168.3	3000	1000	279		25			
	200	219.1	3000	1000	343		29			
	250	273.0	3000	1000	406		30			
	300	324.0	3000	1000	483		32			
	350	356.0	3000	1000	533		35			
	400	406.0	3000	1000	597		37			



#### 2.3.2.7 Transition Design

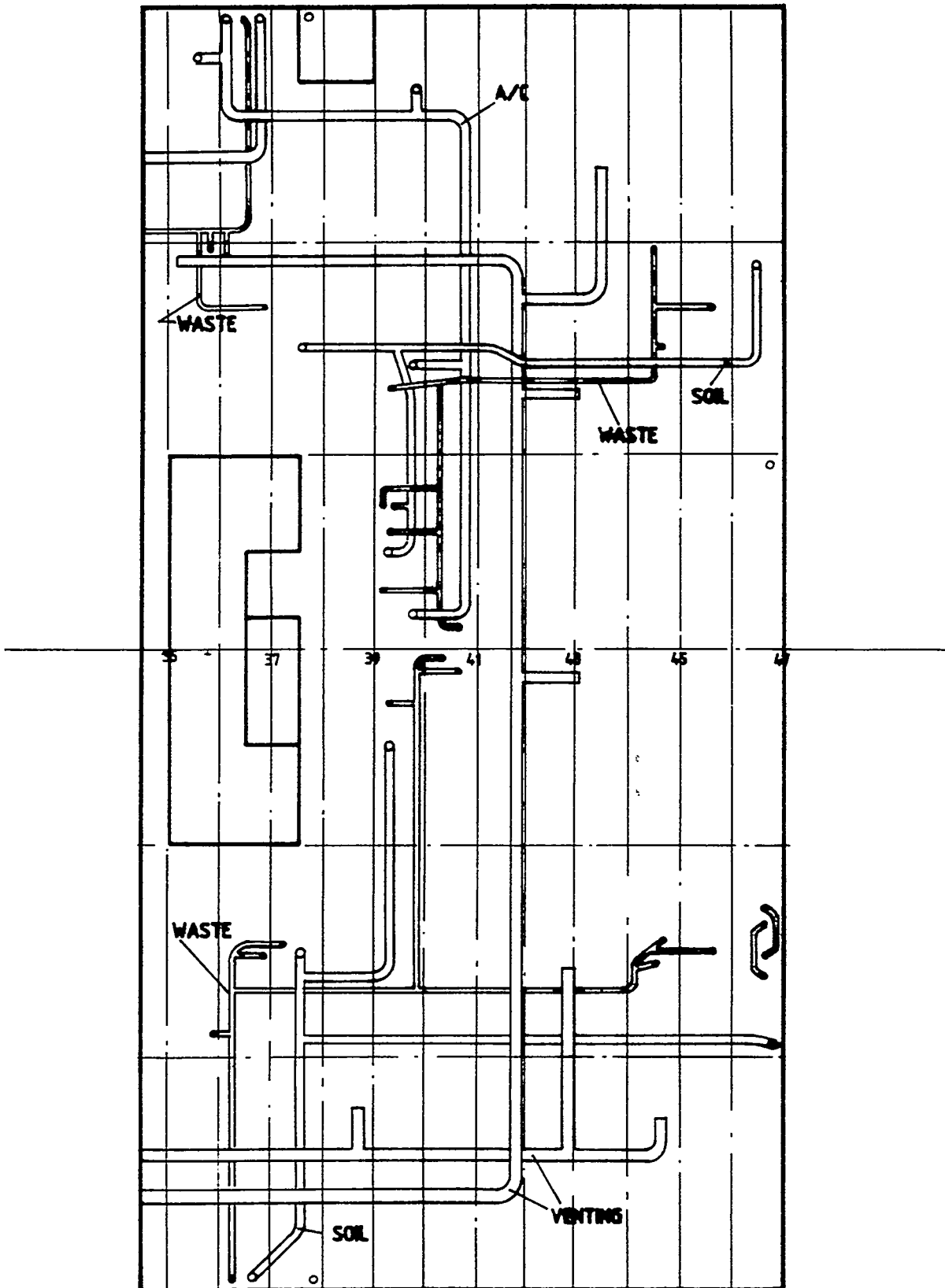
Transition design translates the features of the design from a system orientation to a planning unit orientation in order to establish production requirements at the detail design stage. Elements of the system are developed in steel and outfit zone composites.

One of the major aspects of this work is drawing pipe, vent and cable runs onto a zone, for example producing a steel/outfit composite drawing and for this further pipe production information is required. Similarly, for venting and other systems, production standards must be known.

The main output of the transition design stage is therefore drawings which show the arrangement of outfit items, such as pipes and equipment in relation to the steel structure, having taken into account such items as access and equipment arrangements.

DECKHEAD COMPOSITE

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TRANSITION DESIGN

Information required at the transition design stage overlaps to some extent with the information required for functional design, and consists of:

#### Pi pework

- a) Pipe Sizes - At this stage of design pipe sizes may be identified and therefore the designer must be aware of the yard standards.
- b) Pipe Length - Pipe flanges and connections may also be identified at this stage and therefore standard pipe length data is required.
- c) Pipe Flange Standards
- d) Pipe Bend Radii - Standard radii depending on pipe sizes and material.
- e) Pipe Bend Angle - Standard bend angles, such as 30 degrees, 45 degrees and 90 degrees.
- f) Pipe Hangers Used by Production

#### Venti ng

- a) Bend Angle - Standard or preferred angle.
- b) Bend Radii
- c) Standard Size of Vent Trunking

#### Electrical

- a) Standard Cable Tray Sizes

SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE

### PIPE BEND RADII AND BEND ANGLE

PIPE BEND RADII

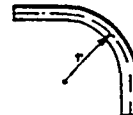
PIPE TYPE	BORE	STANDARD RADIUS	MINIMUM RADIUS



COMMENTS

PIPE BEND ANGLE  
PREFERRED ANGLES

90•



45.

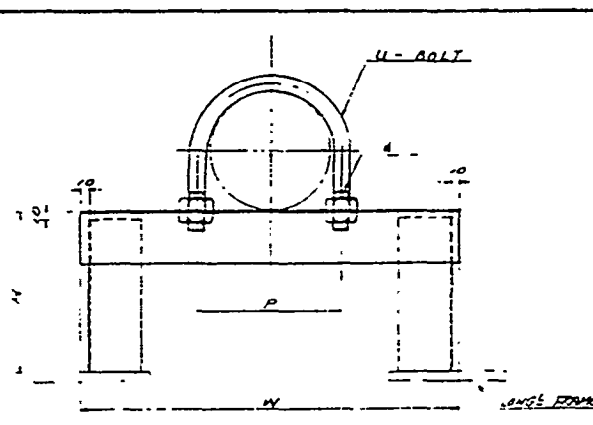


30°/60°



SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE
PIPE SUPPORT			SHEET OF

TYPE - Light Pipe, Type (A)  
 USE - Fitted on longitudinal frames between transverses  
 CODE -



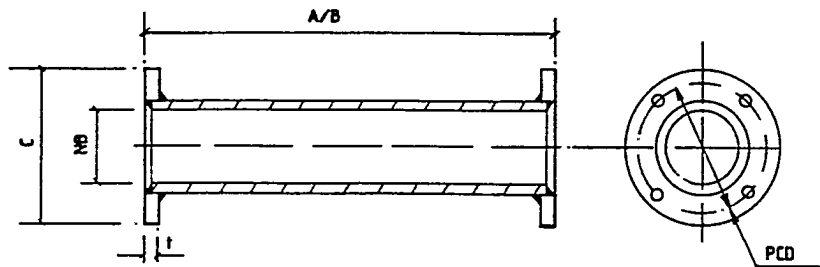
N.D.	ANGLE (SPEL)	P	W	d	UNIT WEIGHT	REMARK
200	75 = 75 = 9	281	1020	H20	35.7	N1200
250	"	291	"	"	36.0	"
300	90 = 90 = 10	347	"	H20	48.1	"
350	"	383	"	"	49.0	"
400	"	435	"	"	49.7	"
450	100 = 100 = 10	481	"	H30	58.7	"
500	"	542	"	"	59.6	"
550	"	589	"	"	59.9	"
600	130 = 130 = 12	651	"	H36	73.9	"
650	"	702	"	"	76.6	"
700	"	753	"	"	76.5	"
750	"	805	"	"	77.8	"
800	150 = 150 = 12	862	1020	H42	120.2	N1200

COMMENTS :-

SHIPYARD NAME	DIAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE

### PIPE BORE , FLANGE AND LENGTH STANDARDS

#### STRAIGHT PIPE



STANDARD No	TUBE				FLANGES			LENGTH		
	NB	O/D			C	D	t	A	B	
	50	60.3	3000	1000	150		19			
	60	73.0	3000	1000	178		22			
	75	88.9	3000	1000	191		24			
	100	114.9	3000	1000	229		24			
	150	168.3	3000	1000	279		25			
	200	219.1	3000	1000	343		29			
	250	273.0	3000	1000	406		30			
	300	324.0	3000	1000	483		32			
	350	356.0	3000	1000	533		35			
	400	406.0	3000	1000	597		37			

### 2.3.2 8 Detail Design

Detail design develops the features of the design necessary to allow local purchasing, piece part fabrication, manufacture and subsequent assembly to be carried out.

To do this work the designer needs detailed information on the shop floor production processes and facility capabilities. Much of the latter requirement is obtained from the work station definitions which are prepared on a standard format listing both the work station capacity and capability.

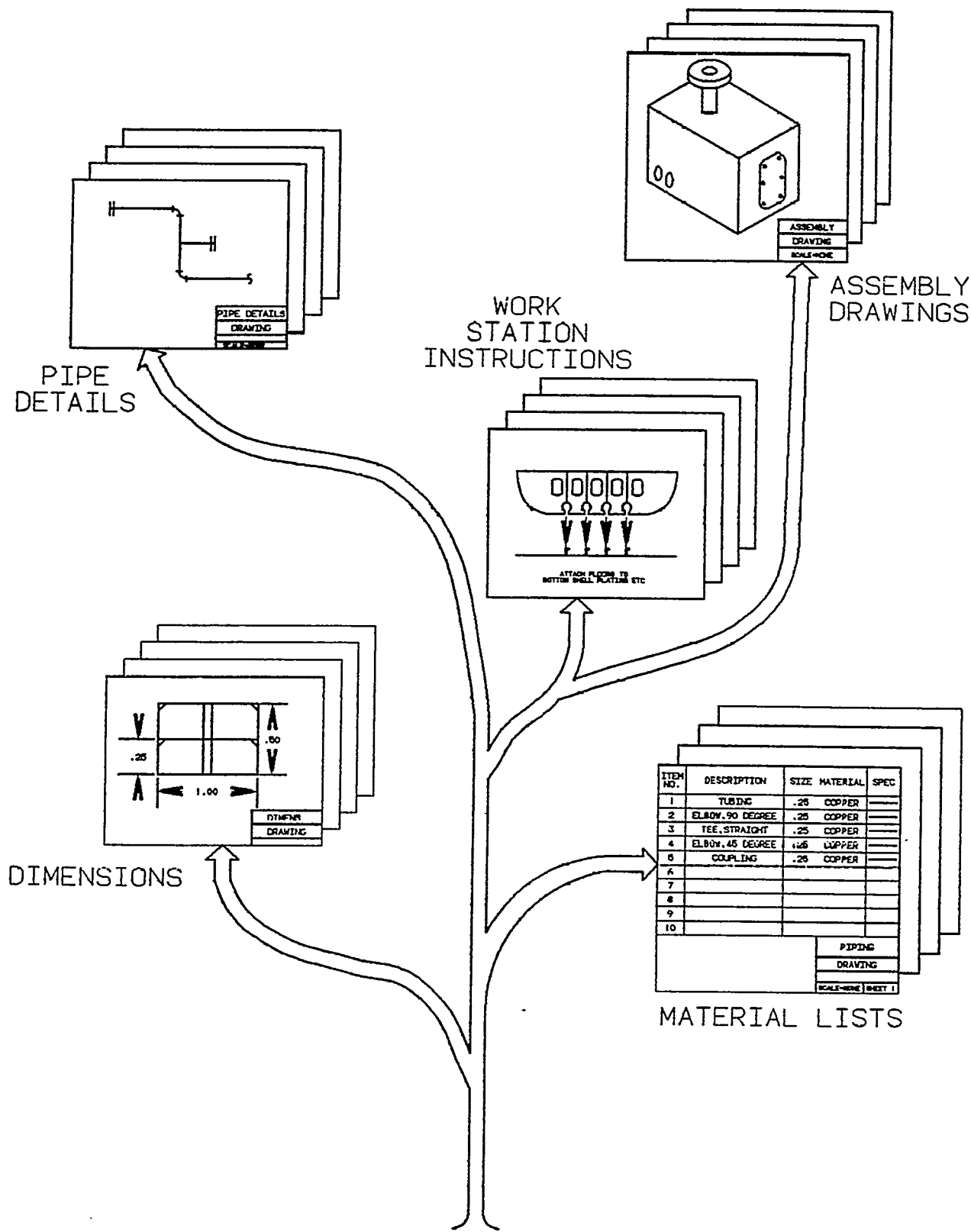
In addition to the work station information, the designer must be aware of standards which are preferred by production, such as cut outs and both steel and outfit connection details.

The output of the detail design stage is production oriented information, such as:

- Work Station Drawings
- Work Instructions
- Dimensional Requirements
- Material Lists

# DETAIL DESIGN OUTPUTS

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work Station Definition includes:

Name.

Code.

Location and physical description.

Area occupied for production purposes.

Process flow diagram.

Product list; a list of materials received into the work station and details of where the materials come from; a list of the products made at the work station and the destination to which these products are normally dispatched.

Product characteristic.

Operational and budget responsibility.

Work output parameters in use.

List of machines (descriptions and codes).

Steady state manning levels on single shift by trade.

Outline drawings giving principal dimensions and accesses in three planes; also crane cover and other physical attributes.

Work Station Capacity

Number of units of output per unit of time or equivalent.

Machine output per unit of time for each machine.

Optimum output for steady state manning on single shift for manual processes.

Statement of capacity to work multiple shifts associated with machine or manpower constraints.

Capacity constraints should be identified, that is manpower, machines and physical area.

SHIPYARD NAME		CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE	

WORKSTATION DEFINITION				
------------------------	--	--	--	--

	NAME	Plate Joining	SHEET 1 OF 5	
	LOCATION	Station 1 of the panel line	CODE PJ01	
	DESCRIPTION	Plates are faired and tacked and then welded using a single sided process, with an automatic submerged arc machine		
	PRODUCT	Flat plate panels		
	CHARACTERISTICS	Two or more rectangular, or approximately rectangular, plates welded together		
	DISPATCHED TO	Station 2 of the panel line for stiffening		
	PRODUCT RECEIVED	CODE	FROM	
	Plate piece parts	PR02	Preparation - flame plane machine	
	PROCESS FLOW DIAGRAM			

Work Station Capability

Machine functions and physical material size processing limits, for example, length, thickness, bore, weight, etc. and tooling available.

Manual skills available required to operate machines or perform manual tasks and current trade allocation to these tasks.

Shipyard services required to perform tasks, for example, welding power, compressed air, water, gas.

SHIPYARD NAME	OWAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE

WORKSTATION DEFINITION
------------------------

NAME	Plate Joining					SHEET 2 OF 5		
CODE	PJ01							
MACHINES								
IDENTITY	DESCRIPTION					CODE		
Welding Machine	Submerged arc, single sided using ceramic backing strip. Single wire, one or more passes							
STEADY STATE MANNING								
2		-	Platers (fairing and tacking)					
1		-	Welder (machine operator)					
3		ALL TRADES						
WORK MEASUREMENT PARAMETERS								
PARAMETER								
VALUE	DATE	REV	VALUE	DATE	REV	VALUE	DATE	REV
8.5	6/6/84		3.6	6/6/84				
OPERATIONAL RESPONSIBILITY								
BUDGET CODE								

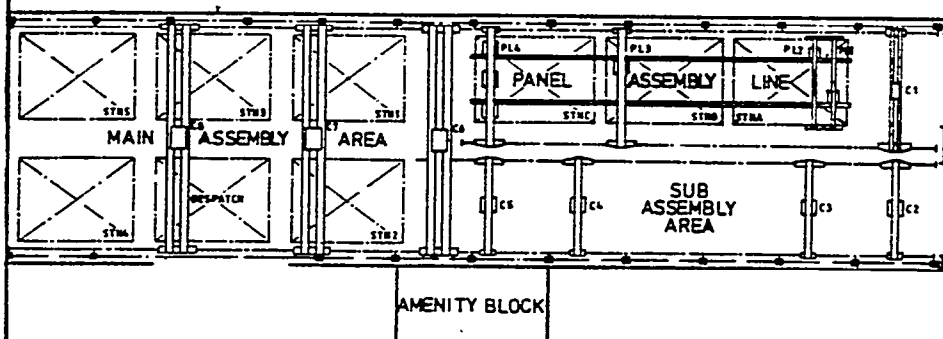
SHIPYARD NAME		CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV	DATE

WORKSTATION CAPACITY	
----------------------	--

NAME	Plate Joining	SHEET 3 OF 5										
CODE	PJ01											
<u>OUTPUT</u>  PRODUCTS/UNIT OF TIME - 15 per week OPTION OUTPUT (1) - MACHINE OUTPUT -												
<table> <thead> <tr> <th>MACHINE</th> <th>OUTPUT</th> </tr> </thead> <tbody> <tr><td>-</td><td>-</td></tr> <tr><td>-</td><td>-</td></tr> <tr><td>-</td><td>-</td></tr> <tr><td>-</td><td>-</td></tr> </tbody> </table>			MACHINE	OUTPUT	-	-	-	-	-	-	-	-
MACHINE	OUTPUT											
-	-											
-	-											
-	-											
-	-											
<b>CAPACITY TO WORK MULTIPLE SHIFTS</b>  Double shift working can be worked, output increased to 30 panels per week												
<b>CAPACITY CONSTRAINTS</b>  Welding machine speed and set-up time limits capacity												
(1) STEADY STATE MANNING ON SINGLE SHIFT (MANUAL PROCESSES)												

SHIPYARD NAME		CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV	DATE
WORKSTATION DEFINITION				
NAME		Plate Joining		
SHEET 4 OF 5				
OUTLINE DRAWINGS				
				
SCALE				

SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV DATE

	<b>WORKSTATION CAPABILITY</b>
--	-------------------------------

NAME Plate Joining	SHEET 5 OF 5						
CODE PJ01							
<u>MACHINE FUNCTIONS AND LIMITS</u> <u>MACHINE IDENTITY</u> <div style="float: right; text-align: right;">CODE _____</div> <p>Welding Machine - Maximum plate length = 25 ft          - Maximum plate thickness = 1.5 ins</p>							
<b>SKILLS REQUIRED</b> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 20%; padding: 5px;">TRADE</th> <th style="padding: 5px;">SKILL</th> </tr> </thead> <tbody> <tr> <td style="padding: 5px;">Plater</td> <td style="padding: 5px;">Read work station drawings Set up plates as defined by drawings Tack plates using mma Check and record dimensions</td> </tr> <tr> <td style="padding: 5px;">Welder</td> <td style="padding: 5px;">Operate welding machine Check for quality Check and record dimensions of panel</td> </tr> </tbody> </table>		TRADE	SKILL	Plater	Read work station drawings Set up plates as defined by drawings Tack plates using mma Check and record dimensions	Welder	Operate welding machine Check for quality Check and record dimensions of panel
TRADE	SKILL						
Plater	Read work station drawings Set up plates as defined by drawings Tack plates using mma Check and record dimensions						
Welder	Operate welding machine Check for quality Check and record dimensions of panel						
<b>SERVICES</b> WELDING POWER COMPRESSED AIR WATER GAS							

### 2.3.3 GUIDELINES FOR PRODUCTION PROCESS AND METHOD INFORMATION DOCUMENTATION

This chapter describes what process and method information should be documented by shipyards for use by both designers and industrial or production engineers. As with the facility capability documentation, a hierarchy of information is developed in line with the five stages of design.

The need to document the production processes and methods is discussed elsewhere, in Volume 2, Part 1, Chapter 8. The documentation produced forms part of the company shipbuilding policy.

Examples of how the required information may best be recorded in readily useable form are included in this chapter.

#### CROSS-REFERENCES

- 2.1.8 The Need to Document Production Process and Method Information.



### 2.3.3.1 Introduction

In order for the design of a ship to be suited to efficient production in a particular shipyard, the designer must be aware, not only of the shipyard facilities, but also of standard or preferred processes and methods used by production. This information must be documented and available to the designer in increasing detail through the design process.

At the earliest design stage the need is for a block breakdown, showing the preferred erection method. This is then extended to information on how each block is assembled. At the detail design level, detailed information is required, such as welding processes and their related edge preparation requirements and accuracy control methods.

### 2.3.3.2 Conceptual Design

The conceptual design process requires two main inputs from production:

#### a) Preliminary Block (Unit) Breakdown

The block or unit breakdown shows, for that type of ship, the preferred division of the complete ship into the blocks (or units) from which it is constructed. This is best done by showing a number of plans and elevations of the ship type with the block joints clearly marked. The breakdown for the ship type is reviewed and amended as necessary by the design and production departments, for the particular ship design, taking into account any unusual design features of the ship, developments in the facility capabilities or changes in production methods.

Design work influenced by the preliminary block breakdown of the ship includes:

overall dimensions,

positions of the primary planes (compartment or hold bulkheads and decks),

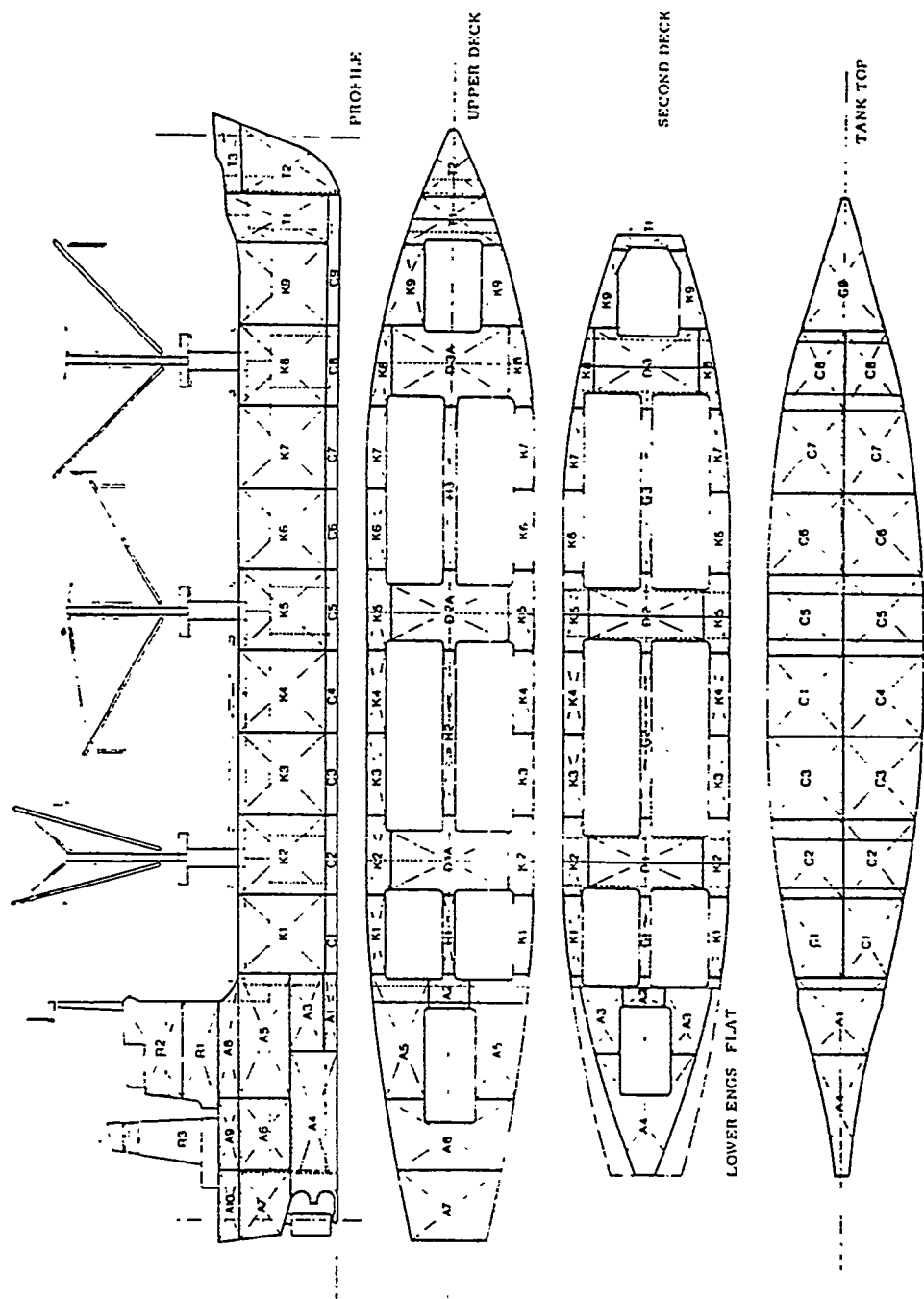
accommodation and superstructure arrangement,

body plan - such as the position of knuckles, start and finish of curvature, camber and sheer.

SHIPYARD NAME	CHAP	SECTION	SHEET No
PRODUCTION METHODS AND PROCESSES			REV
			DATE

BLOCK BREAKDOWN

SHIP TYPE -  
YARD NUMBER/S -



COMMENTS :-

The objective must be to develop a standard approach to the breakdown of ships within a type. This will be done by defining basic rules for the transverse and longitudinal subdivision of the ship. Particular features of the ship may require a move away from the standard but this should only occur in rare instances.

As an example, consider the longitudinal subdivision. The rule should say that the ship be divided into a series of equal length blocks. The length is a function of the plate length that can be handled by the facility and the way in which assemblies map into assembly areas. Frame and transverse spacing will also be significant as the objective will be to produce as many identical blocks as possible.

A further example would be the break in the shell relative to the tank top in the engine room. The rule could be that this should occur at about 3 to 5 feet above the tank top to allow easy access to the welt and also allow extensive pre-outfit of the below floor pipework without making the shell butt impossible to access.

#### b) Erection Sequence

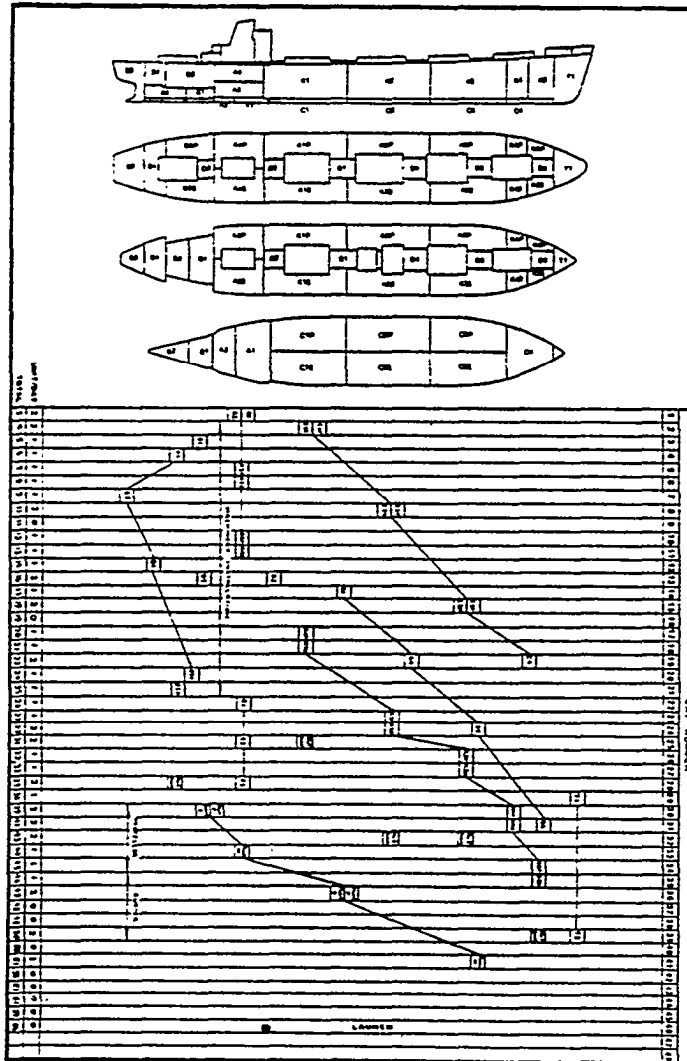
The erection sequence for the ship type shows the order of joining of the blocks (or units) at the construction stage and also identifies the assembly logic. The erection sequence combined with the block breakdown for a ship type is the type plan, and is drawn against arbitrary units of time, such as from 1 to 100. Later in the contract, when calendar dates can be put against the start and completion of construction, the type plan is expanded or contracted and becomes calendar based.

SHIPYARD NAME	CHAP	SECTION	SHEET No
PRODUCTION METHODS AND PROCESSES			REV DATE

## ERECTION SCHEDULE (TYPE PLAN)

SHIP TYPE -

YARD NUMBER/S -



COMMENTS :-

### 2.3.3.3 Contract Design

In order to develop the conceptual design and generate further arrangements piping diagrams and a ship specification the designer must be aware of the standard block assembly methods and general production standards.

Relevant inputs at this design stage are:

#### a) Process Analysis of Block Types

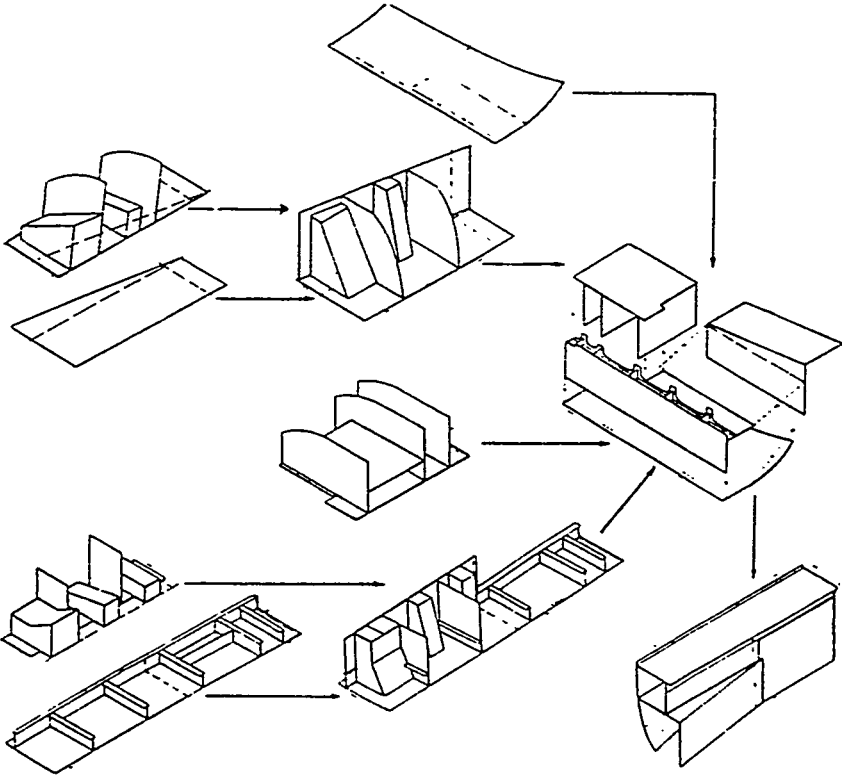
The process analysis of the blocks shows the breakdown of the block into its interim products and the assembly sequence for the block. Painting and outfit requirements are also identified. The process analysis is done for each different block type, such as:

- |                  |  |
|------------------|--|
| Cargo area       | - bottom block<br>side block<br>center block<br>deck block |
| Fore end/aft end | - bottom blocks<br>upper blocks                            |
| Engine Room      | - bottom blocks<br>side blocks<br>center blocks            |

Accommodation

Design outputs influenced by the process analysis are:

- development of the midship section structure
- development of the body plan above and below waterline
- accommodation arrangement
- engine room arrangement

SHIPYARD NAME		CHAP	SECTION	SHEET No
PRODUCTION METHODS AND PROCESSES				REV DATE
BLOCK PROCESS ANALYSIS				
SHIP TYPE - BLOCK TYPE - CODE -				
				
COMMENTS :-				
SEE ALSO :-				

b) Production Standards

Production standards or preferred methods relevant at this level of design are:

Standard outfit unit types, particularly in the engine room.  
Function and overall dimensions are required for each standard outfit unit.

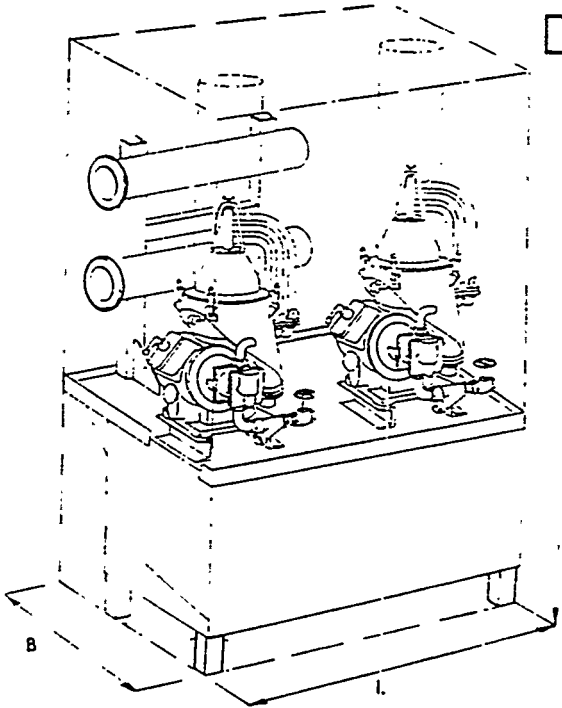
Accommodation standards, such as use of:

- modular accommodation
- coverings for decks, ceilings and bulkheads
- fittings
- arrangement of fittings
- furniture
- arrangement of furniture
- staircases and ladders
- bridge arrangement

c) Treatment and Painting

Treatment methods used in the shipyard at the various production stages are required as are the preferred paint types and painting processes, number of coats, etc. Although the owner will have his own requirements, the designer should ensure that these can be achieved by production.

The production of the ship specification is influenced by the preferred treatment and painting processes.

SHIPYARD NAME		CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION			REV	DATE
OUTFIT UNIT SIZE AND WEIGHT				
<div><div>CODE</div></div>				
NAME				
<div>MAXIMUM SIZE</div> <div>L =      ft ins</div> <div>B =      ft ins</div> <div>H =      ft ins</div> <div>COMMENTS</div>				
<div>MAXIMUM WEIGHT</div> <div>COMMENTS</div>				



#### 2.3.3.4 Functional Design

At the functional design stage more information is required concerning the shop floor processes covering steelwork, outfit and painting. This information allows the design to be developed in line with the preferred production processes and methods.

Information required at this level of design consists of:

##### a) Planning Unit Process Analysis

The planning unit process analysis defines the way in which steel and outfit units are broken down into interim products and the assembly sequence of those products. Specific outfit and painting requirements are defined, such as what outfit is being installed on the unit and at what stage of unit assembly.

Factors influenced by the process analysis are:

The scantling drawings (drawn by system, such as decks, bulkheads, shell).

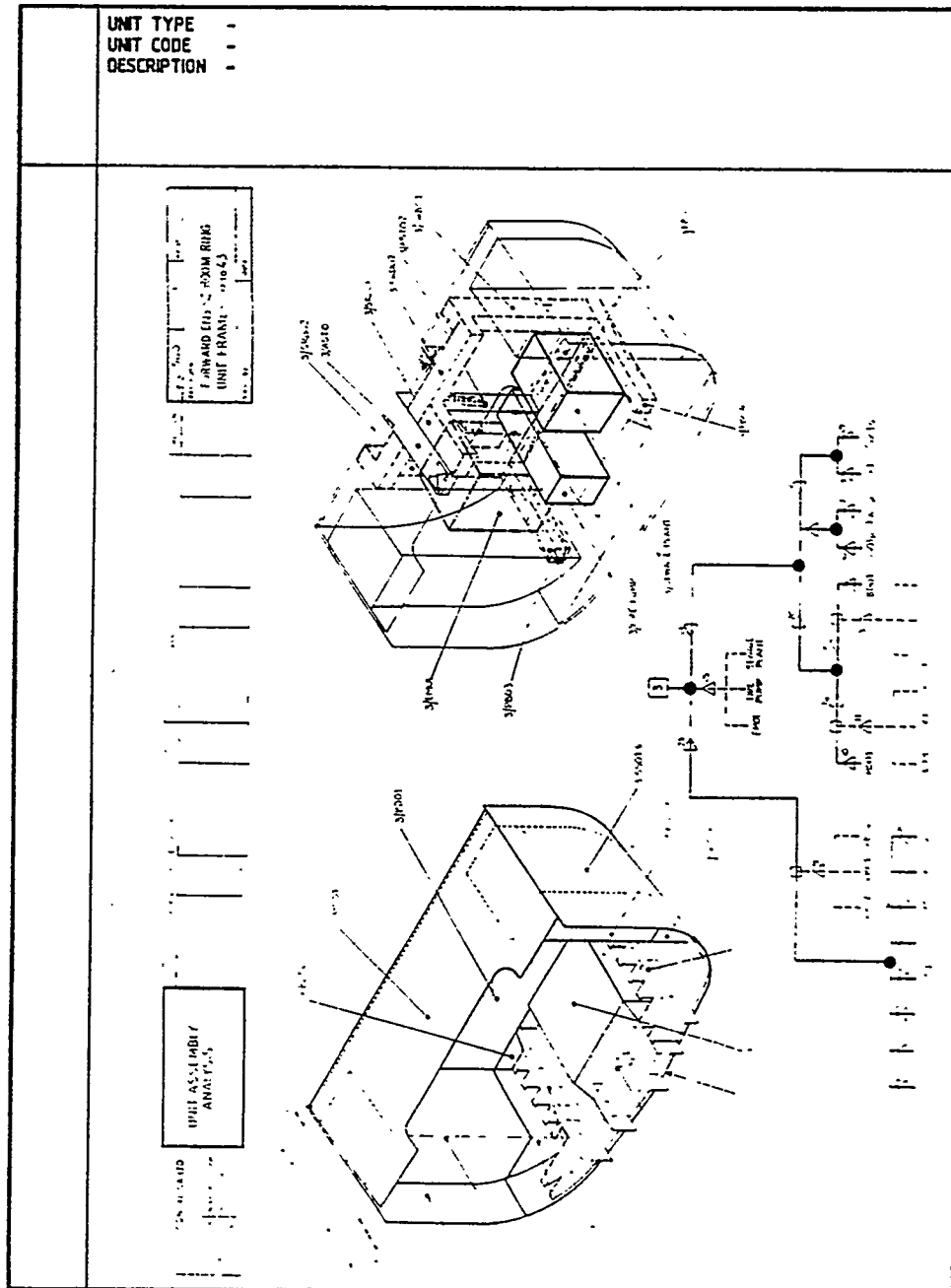
##### b) Assembly Processes and Methods

The assembly processes and methods used on the shop floor are documented by individual workstation. The workstation definitions are discussed in the previous chapter under Facility Capability Documentation.

SHIPYARD NAME	CHAP	SECTION	SHEET No
PRODUCTION METHODS AND PROCESSES			REV DATE

## PROCESS ANALYSIS - STEEL UNIT

UNIT TYPE	-
UNIT CODE	-
DESCRIPTION	-



The way in which the work is done at each stage of production must be known including information on:

- machine processes,
- manual processes,
- fairing methods
- welding methods (manual/semi-automatic or automatic),
- access requirements.

Functional design work influenced by a knowledge of assembly processes and methods includes:

### Structural Design

The structure should be designed so as to suit the assembly methods used on the shop floor, particularly with regard to connection details both for steel structure and outfit assemblies.

### Engine Room Arrangement

The engine room layout and installation of equipment depends upon the assembly and outfit installation methods and the preferred stage of outfit installation, such as on-block or on-board.

#### 2.3.3.5 Transitional Design

Transitional design is the generation of production oriented information, in the form of steel/outfit composite drawings. Much of this work is the definition of pipe runs relative to the structure, and also precise positioning of equipment and machinery, and venting and cable runs.

This task is influenced by:

##### a) Pipe Joining Methods

Preferred methods for joining pipes depending on type, function and position. The use and extent of closing pipe pieces fitted between outfit assemblies which have been installed at earlier production stages.

In conjunction with information on preferred pipe lengths, this allows flange positions to be detailed on the pipe diagrammatics.

##### b) Zone Process Analysis

The zones on the vessel are analyzed to determine the timing and sequence of all installation activities. This allows the designer to ensure that adequate access for installation of systems can be provided.

#### 2.3.3.6 Detail Design

The detail design stage is concerned with the production of workstation drawings and work instructions, material lists and dimensional requirements. These tasks are influenced by:

##### a) The Planning Unit Process Analysis

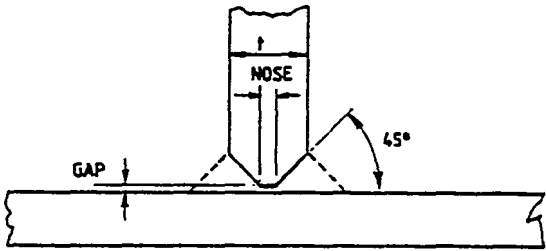
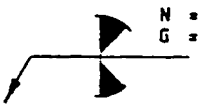
The process analysis for both outfit and steel planning units was discussed in section 2.3.3.4 under the functional design stage.

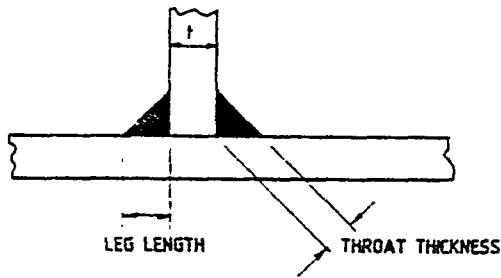
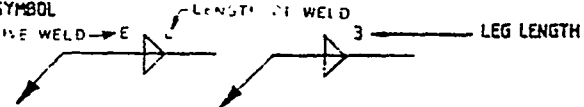
##### b) Welding Edge Preparations

The standard welding methods and the related edge preparations are tabulated for each production stage. This information is required for the production of steel workstation drawings, and is either included on the workstation data sheets or as part of the process analysis.

##### c) Accuracy Control Methods

The methods used for accuracy control checks and dimensional control during assembly are recorded, such as the use of steel tapes, optical devices or custom built aids. Information relating to accuracy control, such as critical points and deck dimensions can be incorporated into the workstation drawings and work instructions. Chapter 2.2.6 discusses the format of workstation information and the incorporation of dimensional checks.

SHIPYARD NAME					CHAP		SECTION		SHEET No																			
PRODUCTION METHODS AND PROCESSES								REV DATE																				
<b>WELDING PROCESSES</b>																												
<div style="display: flex; justify-content: space-between;"> <div> <b>TYPE</b>  <b>PREPARATION</b>  <b>AUTO/MANUAL</b> </div> <div> Fillet - Double Continuous  Double Bevel  Manual </div> </div>																												
<b>DIAGRAM</b> 																												
<b>PLAN SYMBOL</b>  <div style="margin-left: 400px;"> N =  G = </div>																												
<table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr> <th style="width: 10%;">THICKNESS t</th> <th style="width: 10%;">NOSE</th> <th style="width: 10%;">GAP</th> <th style="width: 10%;">POSITION</th> <th style="width: 10%;">ROD TYPE</th> <th style="width: 10%;">NO. OF RUNS</th> <th style="width: 10%;">ROD SIZE</th> <th style="width: 10%;">AMPS</th> <th style="width: 10%;">LEGEND</th> </tr> </thead> <tbody> <tr> <td style="height: 150px;"></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td> C - CAPPING  RUNS  V - VERTICAL  O- OVERHEAD  D- DOWNHAND  *- PREFERRED  VALUE </td> </tr> </tbody> </table>											THICKNESS t	NOSE	GAP	POSITION	ROD TYPE	NO. OF RUNS	ROD SIZE	AMPS	LEGEND									C - CAPPING RUNS V - VERTICAL O- OVERHEAD D- DOWNHAND *- PREFERRED VALUE
THICKNESS t	NOSE	GAP	POSITION	ROD TYPE	NO. OF RUNS	ROD SIZE	AMPS	LEGEND																				
								C - CAPPING RUNS V - VERTICAL O- OVERHEAD D- DOWNHAND *- PREFERRED VALUE																				
<b>COMMENTS ON USE :-</b>																												

SHIPYARD NAME						CHAP	SECTION	SHEET No
PRODUCTION METHODS AND PROCESSES							REV DATE	
<b>WELDING PROCESSES</b>								
TYPE - Fillet, Double Continuous PREPARATION - None AUTO/MANUAL - Manual								
DIAGRAM 								
PLAN SYMBOL 								
THICKNESS t	LEG LENGTH	POSITION	ROD TYPE	NO. OF RUNS	ROD SIZE	AMPS	LEGEND  POSITION V - VERTICAL O - OVERHEAD D - DOWNHAND * - PREFERRED	
COMMENTS ON USE :-								

SHIPYARD NAME	CHAP	SECTION	SHEET No
PRODUCTION METHODS AND PROCESSES			REV DATE

### WELDING PROCESSES

TYPE - Butt, Two Sided  
 PREPARATION - None - Vee  
 AUTO/MANUAL - Automatic Submerged Arc Machine

DIAGRAM



FIG. 1

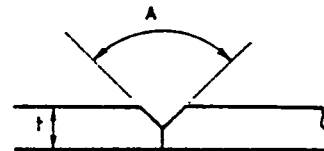


FIG. 2

PLAN SYMBOL

T (in)	Fig. no.	BACKING WELD						FINISHED WELD					
		Amp	Volts	Speed in. in./ min.	Welding wire		A°	Amp	Volts	Speed in. in./ min.	Welding wire		
					dia. (in)	lb./ ft.					dia. (in)	lb./ ft.	
1/4"	1	400	30-34	28-32	5/32	0.09	-	500	30-34	27-32	5/32	0.10	
1/2"	1	475	28-32	48	5/32	0.60	-	600	30-34	48	5/32	0.60	
3/8"	1	500	30-34	28-32	5/32	0.10	-	650	30-34	24-28	5/32	0.14	
3/8"	1	575	30-34	35	3/16	0.10	-	750	30-34	35	3/16	0.13	
1/2"	1	650	31-35	22	3/16	0.18	-	750	31-35	22	3/16	0.20	
1/2"	1	700	31-33	27	3/16	0.16	-	950	34-36	27	3/16	0.16	
5/8"	1	725	31-35	19	3/16	0.25	-	900	32-36	16	3/16	0.34	
5/8"	1	800	32-34	24	3/16	0.20	-	950	34-36	24	3/16	0.24	
5/8"	1	650	30-34	22	3/16	0.18	-	950	31-35	18	3/16	0.32	
3/4"	2	700	31-35	20	1/4	0.19	75	1000	32-36	17	1/4	0.36	
7/8"	2	700	31-35	20	1/4	0.19	60	1100	33-37	15	1/4	0.44	
1"	2	700	31-35	20	1/4	0.19	45	1200	34-38	13	1/4	0.50	

COMMENTS ON USE :-

Used at work station



d) Coordinate Systems and Datum Lines

The datum lines and coordinate system defines the reference points from which dimensions are given. These allow the relevant dimensional information to be entered on the work station drawings.

The illustration shows the definition of datum lines for a ship. There is an origin at the intersection of the aft perpendicular, molded baseline and centerline. The datum lines are waterlines, butts and transverse lines to suit the block lengths.

The use of datum lines allows all directional control to be related to a consistent reference system, which is independent of structure which may lose accuracy during the assembly and construction process.

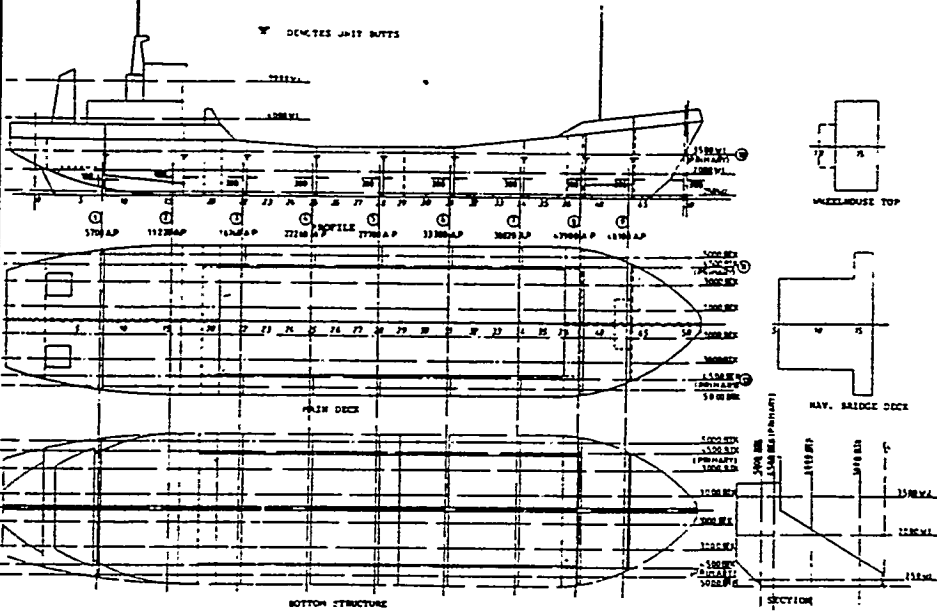
Outfit installation is also related to the same datum system.

SHIPYARD NAME	CHAP	SECTION	SHEET No
PRODUCTION METHODS AND PROCESSES			REV DATE

	<b>DEFINITION OF DATUM LINES</b>
--	----------------------------------

SHIP TYPE -  YARD NUMBER/S -	
------------------------------------	---

COMMENTS :-  Unit butts 1 ft forward of datum lines in way of the cargo hold zone	
---	--

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#### 2.3.4 FEEDBACK FROM PRODUCTION TO DESIGN

Feedback is essential to determine whether or not intended results were achieved. Long term feedback is embodied in the facility and process data for a shipyard. In addition, a format is needed to record problems and suggested changes. This not only gives a basis for discussion between the two functions, but also records the decisions taken as a result.

#### CROSS-REFERENCES

- 2.3.2 Guidelines for Facility Capability Documentation
- 2.3.3 Guidelines for Production Process and Method Information Documentation

#### 2.3.4.1 Introduction

Without feedback from production to design, there is no means of knowing whether an action is successful or not. This chapter discusses the form of feedback information and the means of transferring it.

The long-term information feedback is held in the Facility and process data discussed in the previous two chapters.

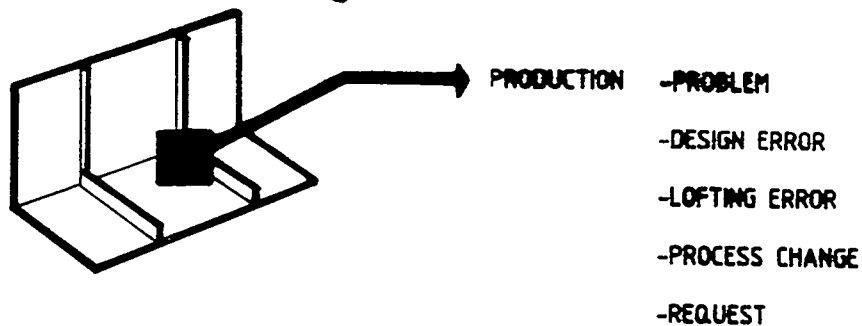
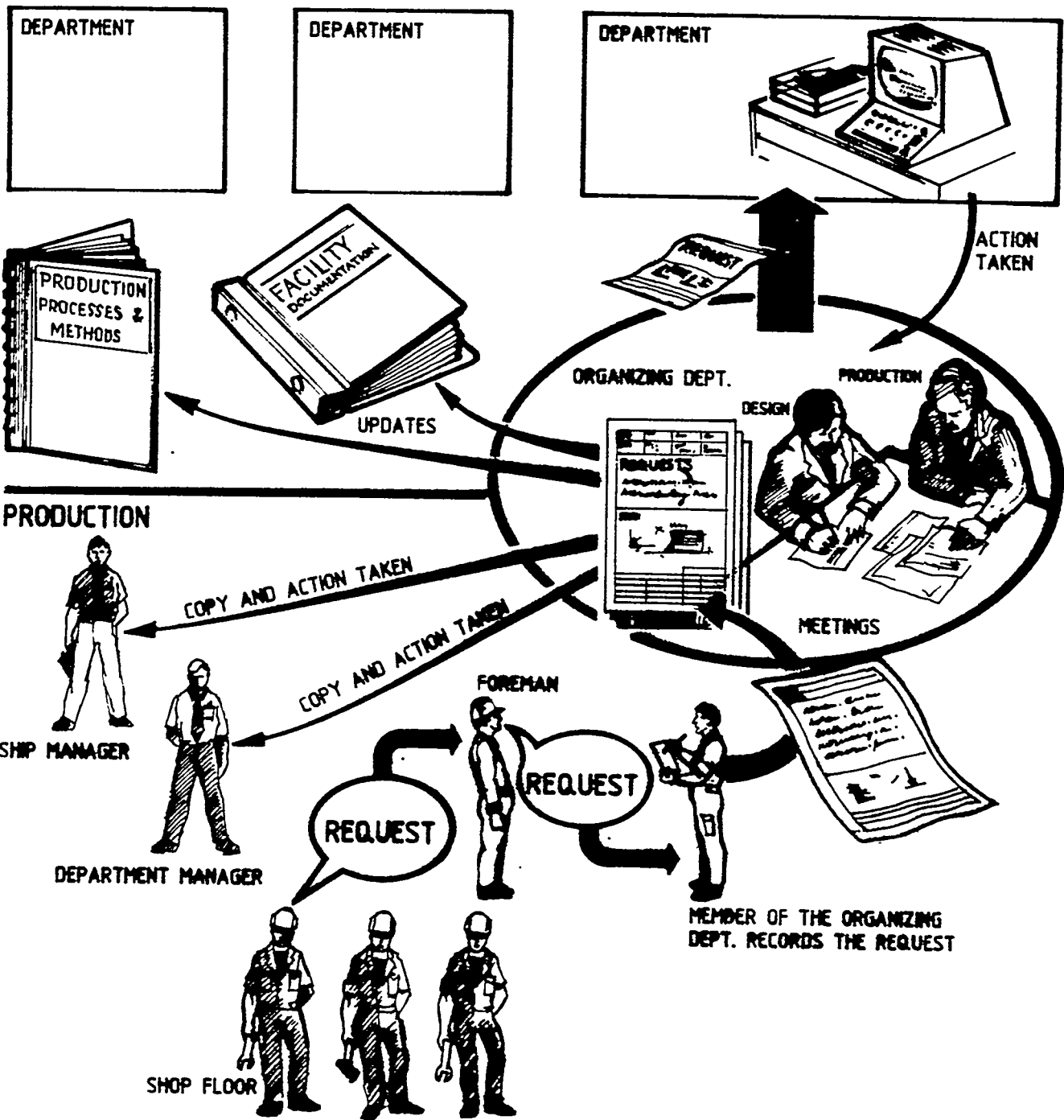
Data collection takes place during and immediately after production. The staff or field engineer provides communication between production and those involved in technical, planning and methods work.

The feedback data is in the form of:

- Suggested changes in design
- Identified problems
- Variations in processes

These must be formalized as proposals, then discussed with production and design before a decision is made on their incorporation in the design process.

## DESIGN



PRODUCTION FEEDBACK SYSTEM

#### 2.3.4.2 The Form of Feedback Information

Feedback Information is best recorded on standard forms, on which requests from the production departments are entered. An example of such a form is shown opposite.

Information recorded on the form is as follows:

Source of the request - department and foreman/manager  
 Date of request  
 Ship Number  
 Unit or Zone identity  
 Drawing identity  
 The request/recommendation  
 Department to which copies are sent, for example:

Design Office  
 Drawing Office  
 QC Department  
 Loft  
 Preparation Department  
 Assembly Department  
 Construction Department

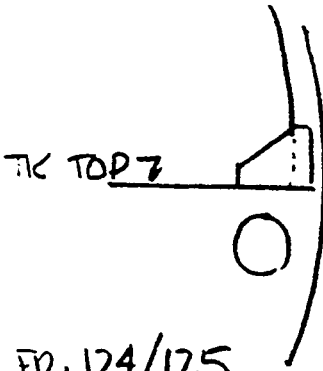
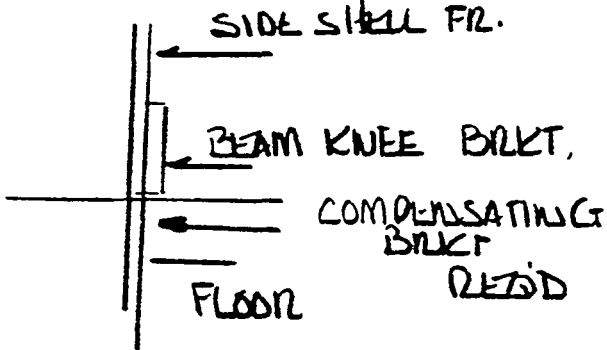
By whom action is to be taken.  
 Date of action

The request, which may also include a recommendation, covers any facet of production which may be influenced by the design departments or of which they should be aware, such as:

information errors, for example wrong dimensions shown on a drawing.

Identified problems, including:

poor structural or outfit details  
 difficulties in production  
 access problems  
 changes in process welding and assembly sequence  
 in accessible joints

SHIP NO. 392	GROUP D62	UNIT NO. CS 03	DRAWING NO. C 5026
DATE 2/5/85	ISSUED BY JUL	REQUESTED BY PLATING DEPT	SIGNATURE <i>Don</i>
<p>REQUEST</p> <p>ON DWG LS035 THE BEAM KNEE BRKTS AT FR 124 &amp; 125 ARE SHOWN LAPPTD ONTO THE SIDE SHELL FRAMES, BECAUSE OF THE LAPPTD CONNECTION. THESE BRKTS DO NOT LINE UP IN THICKNESS WITH THE TANK TOP BEAMS.</p> <p>SURVEYORS HAVE NOTED THE DISCREPANCY AND ARE INSISTING ON COMPENSATING LAPPTD BRKTS BEING FITTED TO THE TANK TOP BEAMS. TO LINE UP WITH KNEE BRACIKETS IT IS REQUESTED FOR 143 SHIP THE DESIGN OF CONNECTIONS BE REVIEWED.</p>			
<p>SKETCH</p> <div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;">  <p>TK TOP</p> <p>FR. 124/125</p> </div> <div style="text-align: center;">  <p>SIDE SHELL FR.</p> <p>BEAM KNEE BRKT.</p> <p>COMPENSATING BRKT</p> <p>FLOOR</p> <p>RETD</p> </div> </div>			
			ACTION REQUESTED BY:
COPIES TO:			
SHIP MGR. ✓	DRAWING OFFICE ✓	IMMEDIATE	
PREP MGR.	LOFT ✓	NEXT SHIP	✓
ASS'Y MGR.	DESIGN OFFICE ✓	LONG TERM	
CONSTRUCTION MGR. ✓			



#### 2.3.4.3 Means of Transferring the Information

The source of the production request is the shopfloor foreman, who should be aware of any problems identified in the work processes under his direct control.

Initially, the problem or error may well be identified by one of the workforce, who, in the course of his working day, will pass on the problem to the foreman above him.

The foreman would then fill in a request form himself when a problem or error occurs, but, because of the reluctance of the shop floor to become involved with paperwork and the filling in of forms, a better arrangement is to have a third party complete them. This third party would be one of the following:

A production engineer who would be assigned specifically to the generation of production feedback information, via the shop floor foremen.

The planner whose duties include production monitoring, who would spend a large proportion of his time on the shop floor and in the process of collecting information on shop floor progress would also fill in the request forms.

The third party must:

Have a general knowledge of shop floor practices

Understand drawings

Have some technical background

Be able to record relevant information concisely

Decisions must be made regarding by whom action must be taken and if the feedback identifies a short-term problem, a long-term problem or both.

This function can be carried out by an organizing department, either:

- within production,

- within design,

- by a separate department; such as a production engineering department.

The advantage of the latter option is that it is neutral, and will not be biased one way or the other regarding the information generated and the actions required.

If the request is short term and will reoccur for the same vessel or the succeeding vessel, action is required immediately and the relevant design, drawing and loft departments are sent copies of the form, as are the relevant shop manager and ship managers.

If the production information is at fault such as a Wrong dimension, edge preparation or drawing, and the solution is obvious, the relevant department such as the drawing office or loft correct the error and notify the organizing department that they have done so.

If the request is long-term, then the facility capability and production process and method documentation must be updated. This would be done following a regular meeting between design, production and production engineering during which the relevant requests would be discussed and solutions approved.

The design department, having received a request made by production will attempt to find a satisfactory solution. Their decision is then fed back to the organizing department, who keep and update feedback records and ensure that action is taken where necessary.

When the design work is being done outside the shipyard, such as an external design office, request forms are sent to the design office and the action taken is then fed back to the shipyard.

Regular meetings should be held between the shipyard and the design office to discuss any problems which are not readily overcome.

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VOLUME 2

DESIGN/PRODUCTION INFORMATION

PART 4

PLANNING

2.4 PLANNINGContents

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#### 2. 4. 1 STRUCTURE AND ORGANIZATION OF PLANNING

This chapter briefly outlines the levels of planning required and the overall flow of information between them. Interfaces between planning and other functions are shown on an overall flow chart.

#### CROSS-REFERENCES

- 1. 2        Shipbuilding Policy Development
- 2. 4. 2     Strategic Planning
- 2. 4. 3     Tactical Planning
- 2. 4. 4     Detail Planning

## 2.4.1 STRUCTURE AND ORGANIZATION OF PLANNING

### 2.4.1.1 Structure and Organization of Planning

Planning covers a range of activities, from overall assessment of the workload on a facility to the detailed scheduling of a work station.

The planning function can be conveniently divided into three levels which correspond to stages of design and production engineering.

The three levels identified are:

Strategic, long term planning beyond the current order book

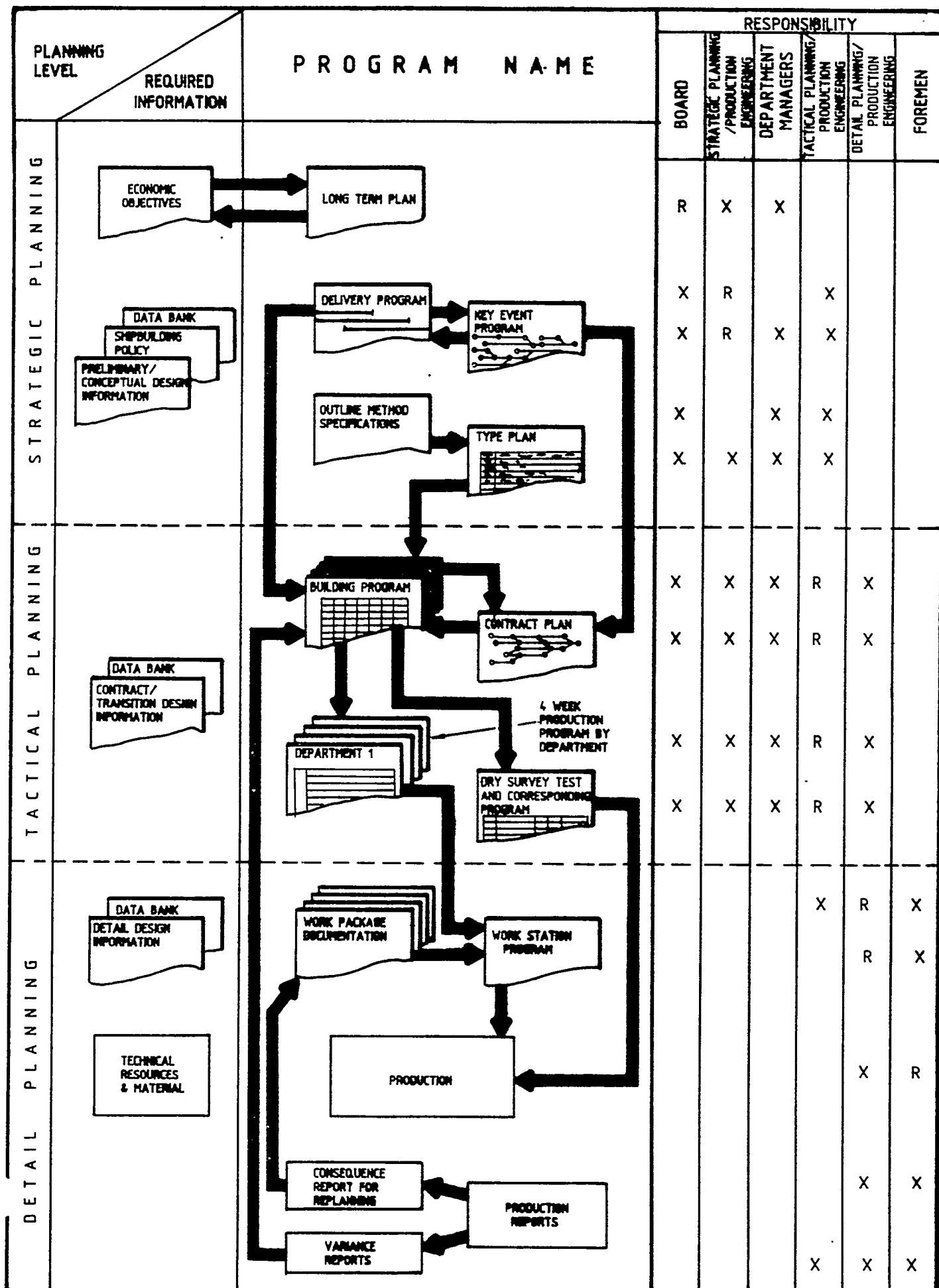
Tactical, the preparation of an overall program for each contract and a corresponding program for each department.

Detail, the production of detailed schedules for individual work stations.

The three levels of planning are designed to present a structured flow of planning processes and information.

The figure opposite shows the relationships between responsible (R) and participating (X) functions at each planning level.





Given the three levels of planning, there are a number of organizational choices open. The first may be represented as follows:

Strategic	Centralized
Tactical Detail	Decentralized

Using this type of organization, it is possible to move planners and production engineers between the tactical and detail levels. On complex projects, like warships, this is a major advantage as a planner can start his work at the tactical level and move down to the detail level as the job progresses. This ability to live with the job is extremely useful and makes it possible for the planner to provide a more effective service to production at the detail level than if a handover were to be organized between tactical and detail.

The main disadvantage of this approach is that at the tactical level there is a need for very close integration between steel and outfit production engineers and planners. This will make it possible to ensure that all aspects of the job are considered stage by stage.

The alternative organization would be to centralize strategic and tactical and decentralize the detail level:

Strategic Tactical	Centralized
Detail	Decentralized

The organization of continuity between tactical and detail as described above becomes more difficult in this case.

From an organization structure point of view a number of alternatives are possible:

- to have a separate planning and production engineering function controlled by its own Vice-President,

- to have the centralized element as a service function to the President of the company with the decentralized elements reporting to local management,

- to have the centralized element as part of an overall pre-production function, again, with the decentralized element reporting to local management.

In organization, there are no absolutes; the local environment, history and personalities will all have a bearing on the definition of an organization that will work effectively.

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#### 2. 4. 2     STRATEGIC PLANNING

This chapter describes the activities carried out at the strategic planning level and the links between strategic planning and other functions. Strategic planning is long-term planning with a time horizon of five years or longer.

#### CROSS-REFERENCES

2. 4. 1 Structure & Organization of Planning

2. 2. 1 Conceptual Design

2. 2. 2 Contract Design

1. 2. 3 Implementation of Shipbuilding Policy

## 2.4.2 STRATEGIC PLANNING

### 2.4.2.1 Introduction

This level of planning is concerned with a long-term horizon beyond the current order book. The flow chart on page 2-4 /203 shows the principal information flows and the interfaces with other activities and functions. The numbers in parentheses in the subheadings below refer to the numbered boxes in the flow chart.

### 2.4.2.2 Strategic Planning Elements

#### Conceptual/Contract Design (1)

The designer's aim is to carry out his function in such a way as to maximize the Company's profitability. There are two ways he can achieve this:

By making the design more functionally attractive to the potential owner, by increasing the quality, economy and longevity of the ship and so increasing the probability of winning orders.

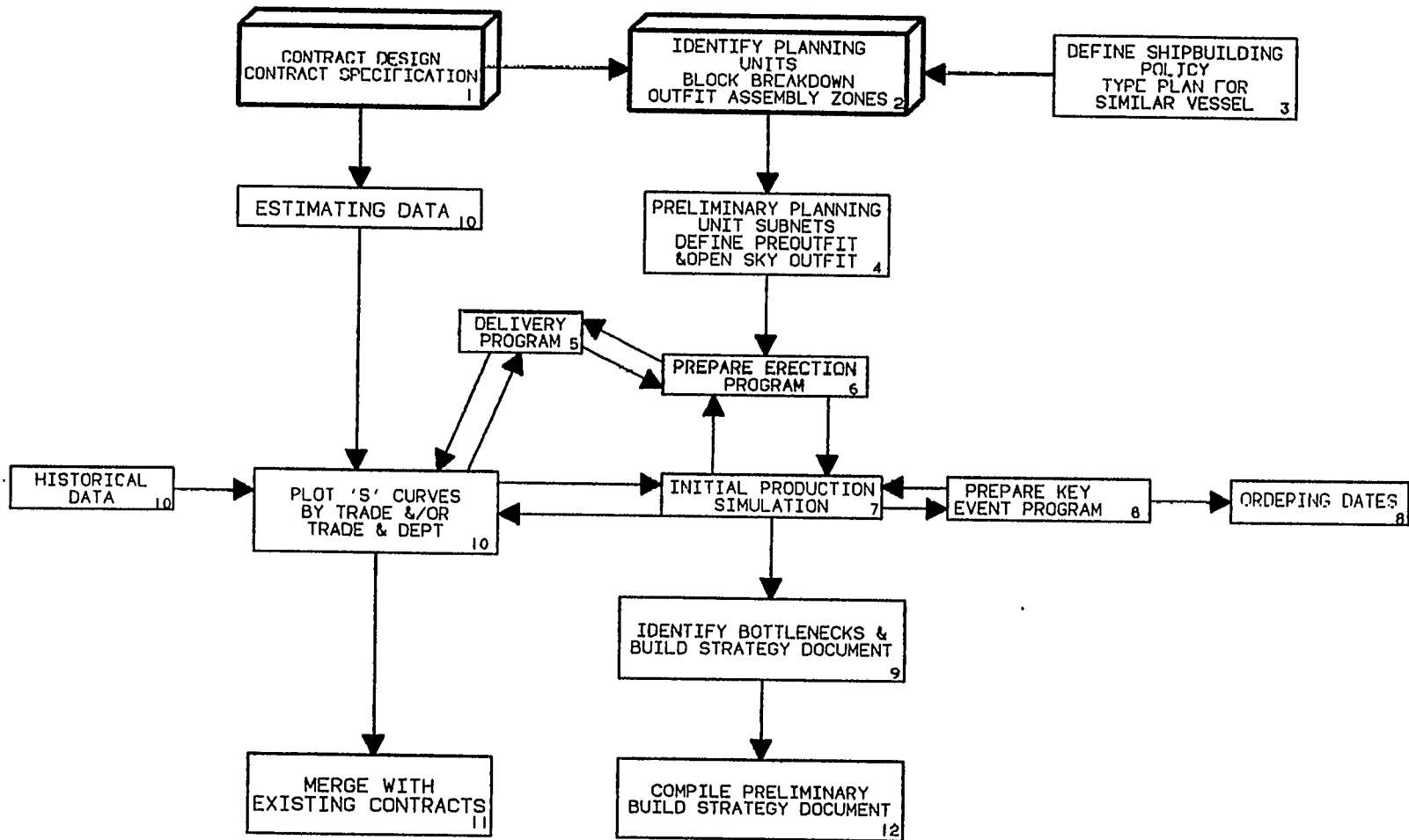
By making the design more production kindly and hence making it possible for the ship to be built more quickly and at a lower cost.

Production engineers will use the outputs of contract design to define an initial block breakdown and identify planning units. The planning units will be the basis of the erection schedule, delivery and key event programs.

#### Planning Units (2)

Planning Units are the control entity around which planning and production engineering are organized. Typically, planning units will be:

# STRATEGIC PLANNING



A steel block or a pair of blocks port and starboard (whichever is appropriate to the block breakdown of a particular ship).

An outfit assembly.

An onboard zone.

Such planning units form the basis for all planning, production engineering, production control and progress reporting.

### Shipbuilding Policy (3)

One major objective of the company shipbuilding policy is to define the optimum build method for each ship type in the company's product range. The policy will set out the ideal subdivision of the ship into planning units and interim products. From a planning point of view, the key element in the policy will be the type plan. The type plan shows the timescale and sequence of the erection and completion of the planning units.

### Preliminary Subnets (4)

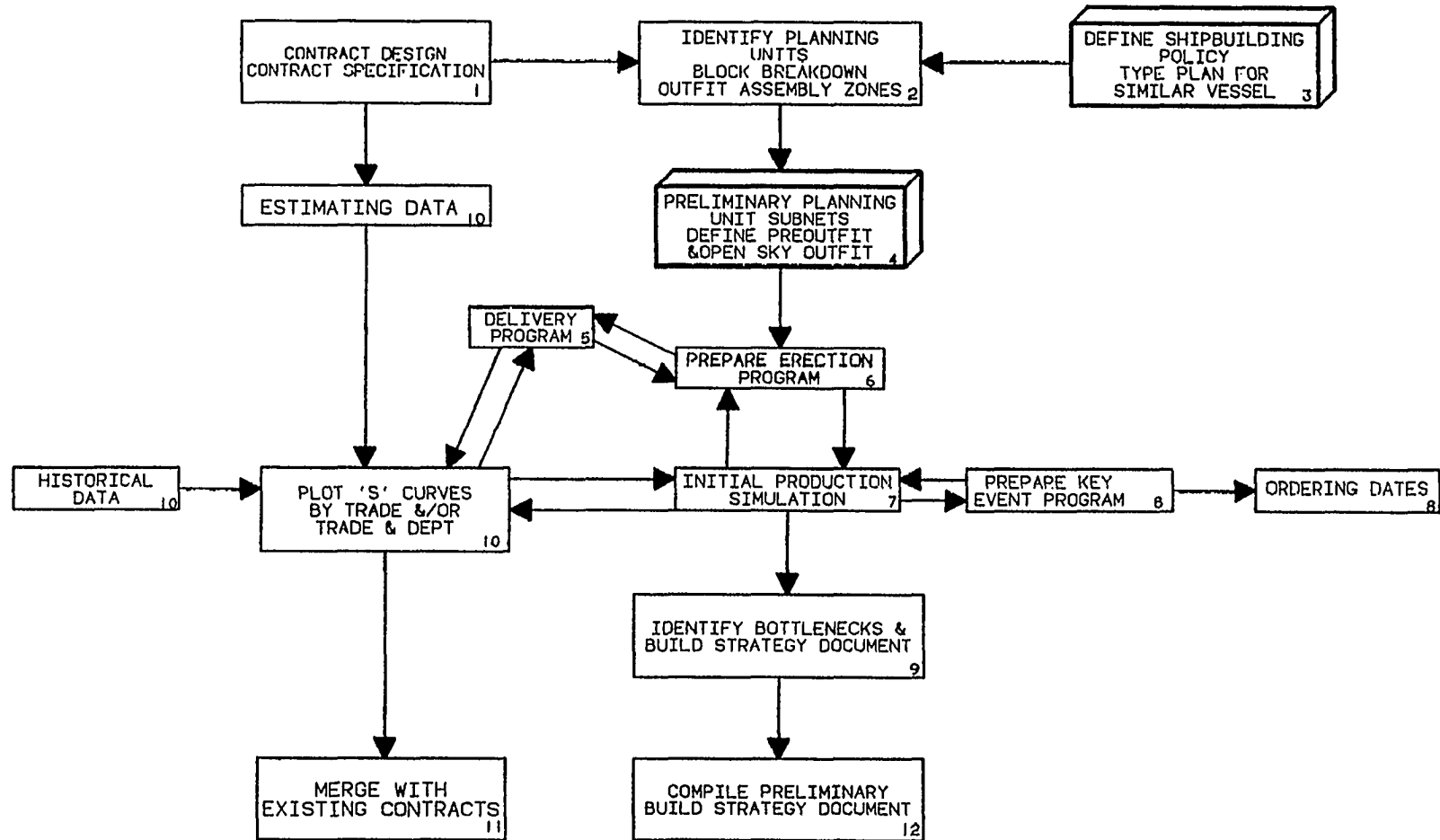
Subnets are prepared to show the sequence of activities required to complete a planning unit and the logical relationships between activities.

Initially, the subnets will be used to quantify the approximate volume of throughput required at a departmental level. The calculation will be based on a preliminary process analysis of typical planning units.

Later, tactical level production engineers will develop detailed process analysis sheets for each individual planning unit as more technical information becomes available.



# STRATEGIC PLANNING



### Delivery Program (5)

The delivery program is a simple program that shows how each contract makes use of the key shipyard facility - the building berth or dock. The plan will therefore show the contract signing date, the keel and launch dates and the delivery date. The keel date must obviously be related to the berth or dock availability and fit into the required cycle of dock floodings and ship movements in those yards with building docks. Utilization of outfit quays is also assessed from this program.

### Erection Program (6)

The definition of planning units will be used as the basis for development of the erection sequence. This sequence is then fitted into the construction time frame defined in the delivery program to produce an erection program. Alternative erection sequences can be assessed using a simple network to calculate schedules and critical paths. There will be an iteration as the erection program, delivery program and resource requirements are brought into balance.

### Initial Production Simulation (7)

Each planning unit is defined on the erection program and each planning unit has a subnetwork. Therefore, each planning unit subnetwork can be given a scheduled end date and each activity on the subnetwork can then be dated.

Each activity on the subnetwork identifies work to be done in a specific department. It should be noted that activities do not cross departmental barriers. It is therefore possible to sort activities by department and print a department program. The workload on the department can thus be assessed.



The technical function, at the detail design level, should be included on the planning unit subnetworks so that the timing and frequency of its output is calculated as for other departments.

Similarly all the activities for a contract can be printed to provide an overall contract building program.

#### Key Event Program and Ordering Dates (8)

A key event program, typically of about 50 key event dates, will be prepared from the initial production simulation. The objective is to set key event dates which can be monitored and reported to senior management as a record of contract progress.

Ordering dates can be obtained from the key event program. These dates are guidance dates calculated early in the life of the contract to enable purchasing to start.

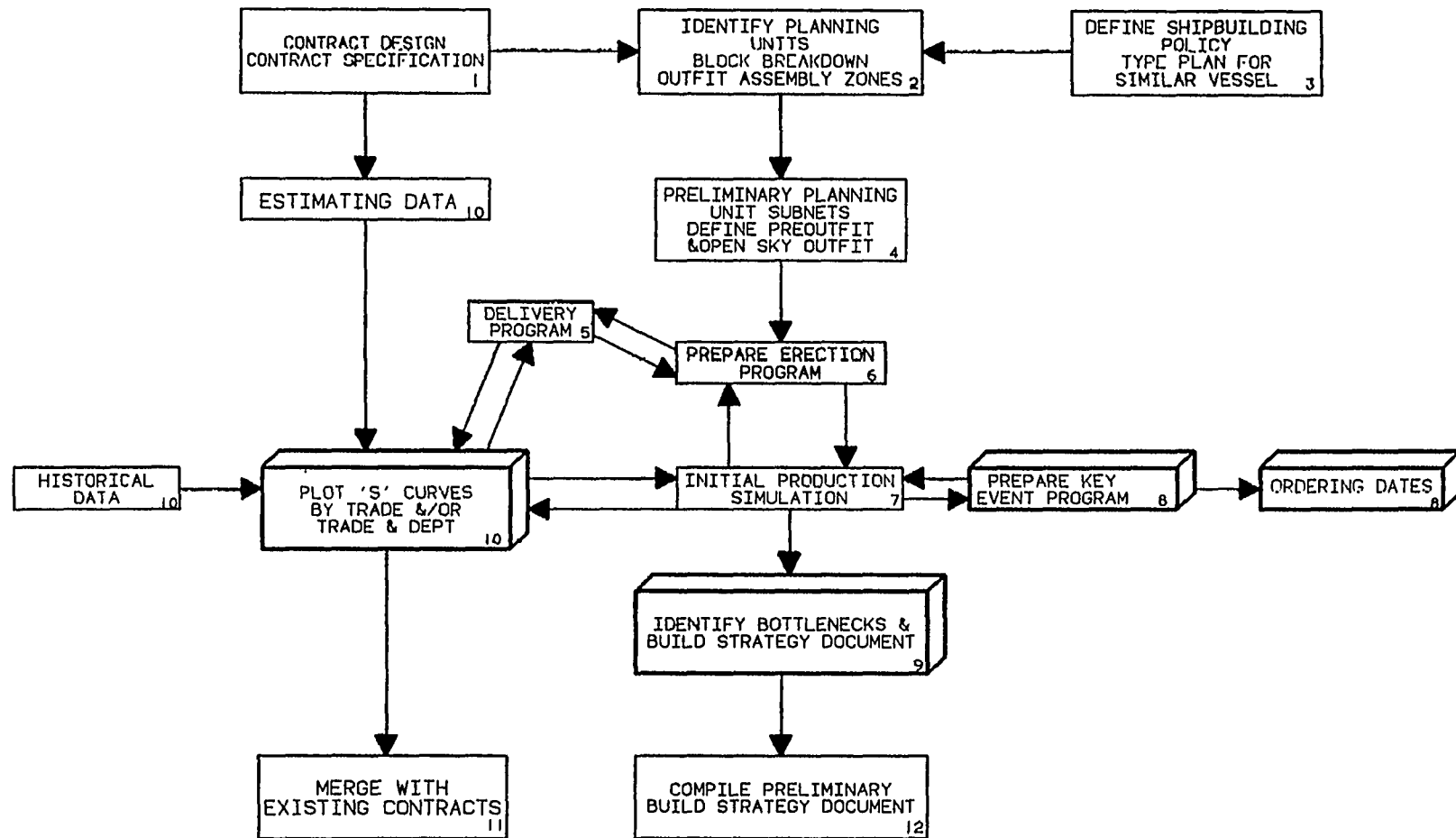
#### Identify Bottlenecks and Subcontract Requirements (9)

The initial production simulation will have enabled workloads by department to be assessed. If overloads exist, these constitute bottlenecks to the achievement of the program. The bottleneck can be overcome by rescheduling, use of overtime or by subcontracting. Subcontract requirements are reviewed on the basis of a calculation of department workloads.

#### Plot "S" Curves (10)

Contract "S" curves will be prepared from historical data. The historical data will usually be held in the form of normalized "S" curves defined from information collected on previous contracts

## STRATEGIC PLANNING



Once an overall contract program has been prepared the contract "S" curves can be fixed in time. The contract "S" curves can then be added to the overall resource requirements for the existing workload. It will then be possible to identify where and when overloads occur.

At the strategic level, all of the above will be carried out on the basis of a preliminary process analysis of typical planning units. The sequence of activities will be reported at the tactical level when a process analysis is available for all planning units.

### 2.4.3 TACTICAL PLANNING

This chapter describes the activities carried out at the tactical planning level and the links between tactical planning and other functions. Tactical planning is medium term planning with a time horizon of about three months.

#### CROSS-REFERENCES

- 1.2.4 Contract Build Strategy
- 2.2.3 Functional Design
- 2.4.1 Structure & Organization of Planning

### 2. 4. 3 TACTICAL PLANNING

#### 2. 4. 3. 1 Introduction

Tactical planning is the process of developing, from the preliminary build strategy, a more detailed contract building program and department program.

The figure on page 2-4/303 illustrates the tactical planning steps and their interfaces with other functions. The numbered steps are described below.

#### 2. 4. 3. 2 Tactical Planning Elements

##### Functional and Transition Design (1)

The outputs of functional and transition design are used by tactical production engineers to carry out process analysis work for all planning units. The process analysis will be used by tactical planners to develop detailed and accurate planning unit subnetworks.

##### Build Strategy Document (Preliminary) (2)

The preliminary build strategy document is a further input to the tactical planning work. It provides the overall planning framework within which tactical planning must be carried out.

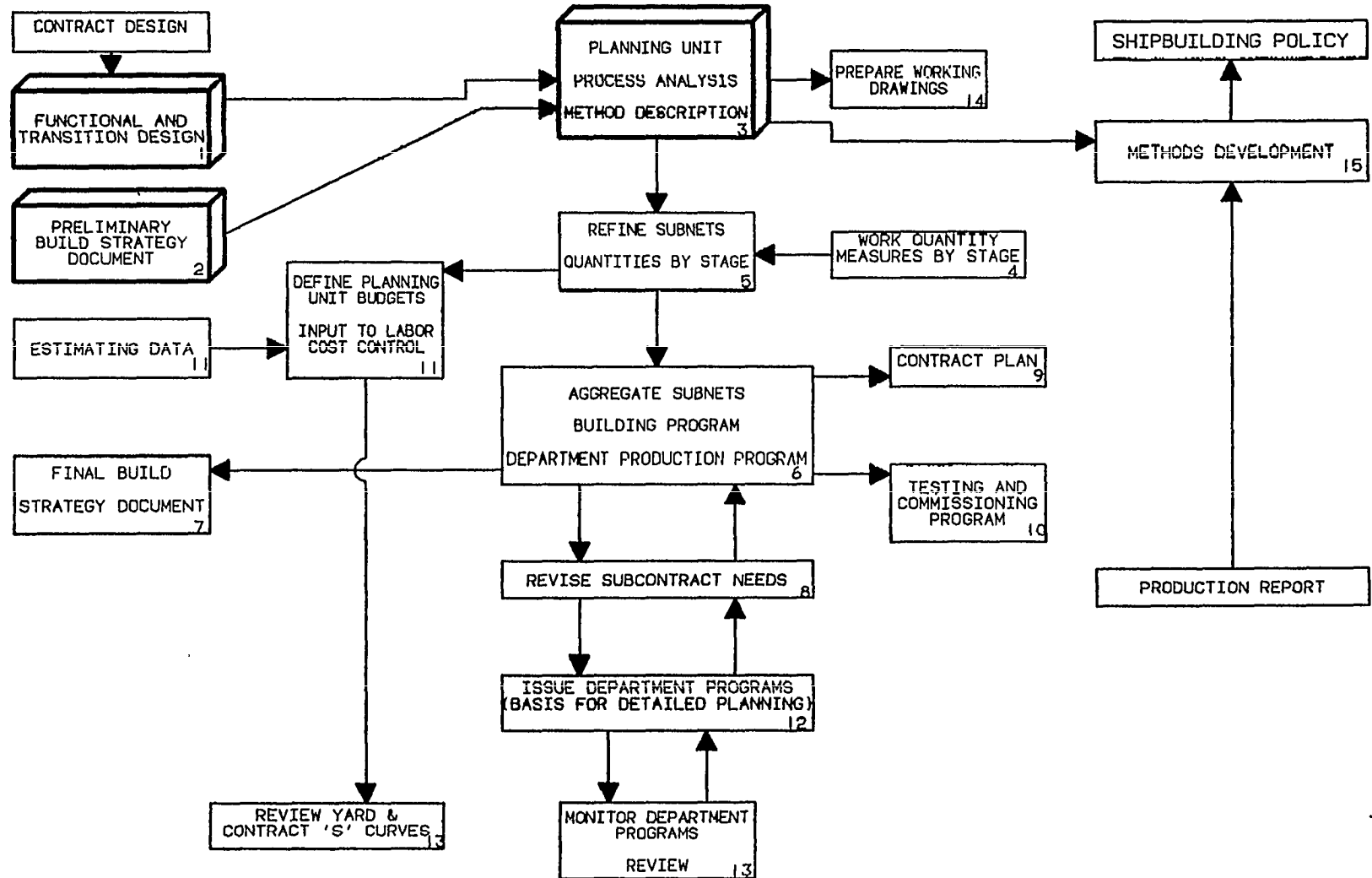
##### Process Analysis (3)

Process analysis is carried out by production engineers working at the tactical level. The objective of the work is to define what work must be carried out to complete each planning unit; at what production stage and work station the work should be carried out; how the work should be carried out, and the production process and overall sequence of activities.

The process analysis allows tactical planning work to proceed and is a key input to detail design.



## TACTICAL PLANNING



#### Work Quantity Measures by Stage (4)

Work quantity measures are required that can be calculated easily from the outputs of process analysis. Given simple parameters it will be possible to quantify the volume of throughput required from a department that can easily be tested against the capacity of the department. Typical measures would be numbers of pipes, numbers of panels, number of outfit assemblies, area of insulation area of paintwork, etc.

#### Quantify the Planning Unit Subnetworks (5)

Standard subnetworks for each planning unit type will have already been defined at the strategic level. The measures of work quantity by stage will be used to determine the times to be allowed at each stage and the buffer times between stages and work stations within a stage. The manhour content of each planning unit by stage will also be calculated.

#### Aggregate Subnetworks (6)

The erection schedule allows end dates to be defined for each planning unit subnetwork. The start and finish dates for each subnetwork activity can now be calculated. A computer network analysis package can be used to aggregate the subnets and calculate rates of flow through each work station and stage in terms of the work quantity measures already discussed. These flow rates can then be compared with capacity. Adjustments may be necessary, indeed a review of subcontract policy may be necessary. When an achievable program is developed the contract building program and department production program can be printed. Both programs are based on the planning units.



### Final Build Strategy Document (7)

Process analysis has been carried out for each planning unit and tactical planning has been carried out as described. It is now necessary to review and update the build strategy document prepared at the strategic level to produce a final build strategy document.

### Review Subcontract (8)

The preparation of the contract building program and the department programs may highlight bottlenecks that cannot be overcome adjustment of internal resources. Conventionally, one solution would be to extend the program to allow peaks in resource requirement to be smoothed. This must be avoided if possible, as by doing so, the commercial objectives are put at risk. The aim must be to maintain the build cycle that enables the commercial objectives to be achieved. Bottlenecks should be overcome in some other way - either by subcontracting, increasing manpower or possibly developing new facilities.

### Contract Plan (9)

The contract plan is a development and extension of the key event program. The contract plan will have 100 or more events and be based on the contract building program and department production program. The purpose of this plan is to provide management with a clear overview of the contract during production, and it would be updated and presented monthly.



### Testing and Commissioning Program (10)

The contract building program and department production program are planning unit based. There is a need for a schedule that is system based in order to control the final stages of testing and commissioning. The program would normally be drawn as a network, although bar charts could be used.

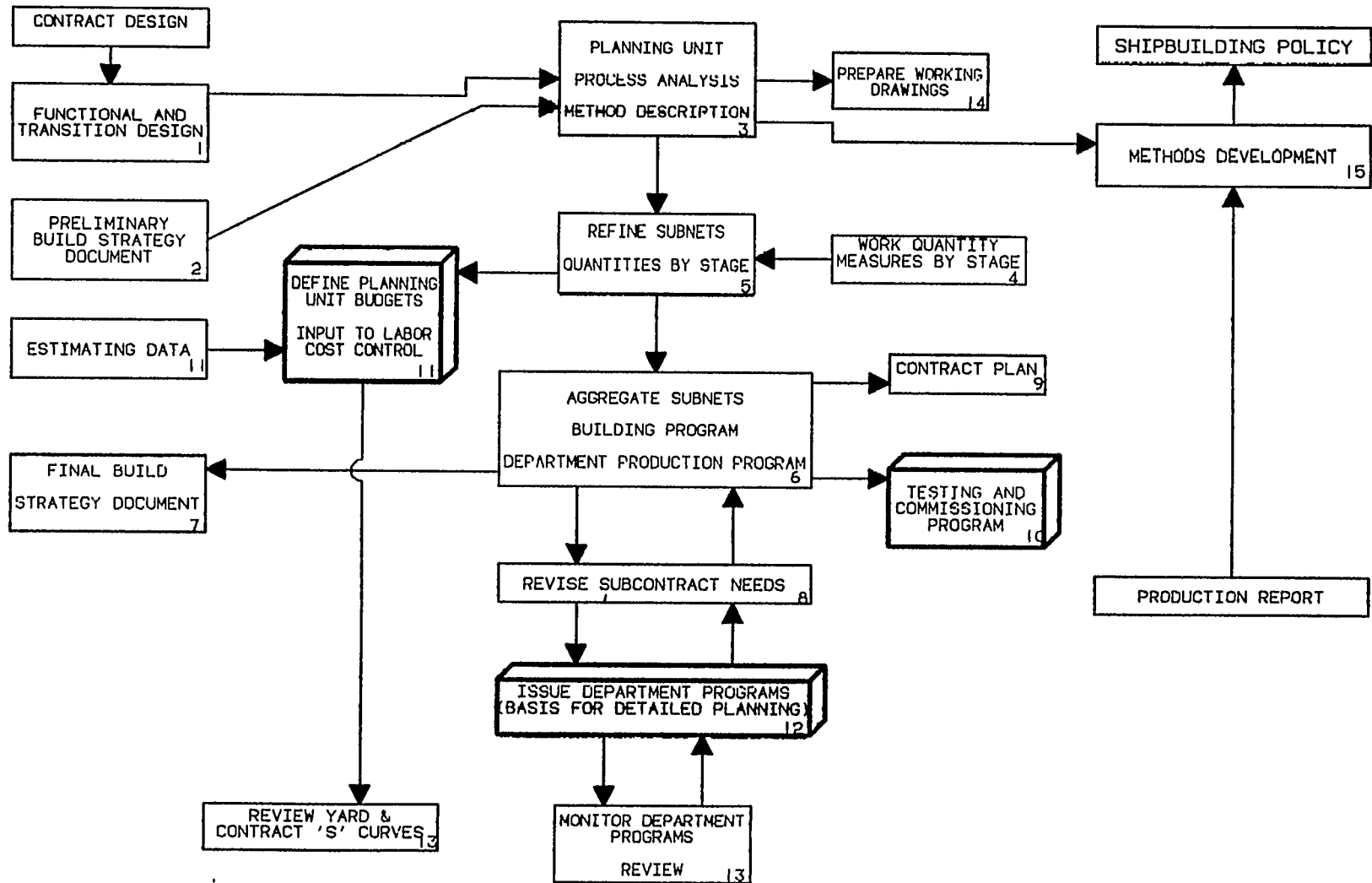
### Define Planning Unit Budgets (11)

Inputs to this process will be the original estimating data, the resource calculations carried out at the strategic planning stage, and the process analysis work. Budgets will be developed on the basis of the quantities of product to be processed at each stage. This is done in part in (5) above when manhours are allocated to the various production stages for each subnet.

### Issue Department Production Programs (12)

The programs will be issued to detail planning on a rolling basis, normally covering a period ahead of six weeks. Four weeks would be a minimum and there would be little point in issuing a schedule covering a period greater than 12 weeks. The main aim is to define the Tactical Plan and stick to it.

## TACTICAL PLANNING



### Monitor Department Program and Manhours Spent (13)

The department programs are based on planning units and monitoring will be carried out on the basis of whether the department achieved its target in terms of planning unit completion. If so, then all is well, if not, then action needs to be taken. This is a significant change from current practice where the question asked is whether the department achieved the required throughput measured in terms of tons, joint length, number of drawings, etc. The conventional approach rarely follows up to ask whether the tons produced were the right tons for this week. In other words, under the new approach, much greater stress is placed on achieving the schedule, for if the schedule is achieved, the commercial objectives will be achieved and the tons per week are irrelevant.

Manhour expenditures by planning unit will also be monitored. The basis, therefore, for the labor cost control system at this level will be the planning unit.

### Prepare Working Drawings (14)

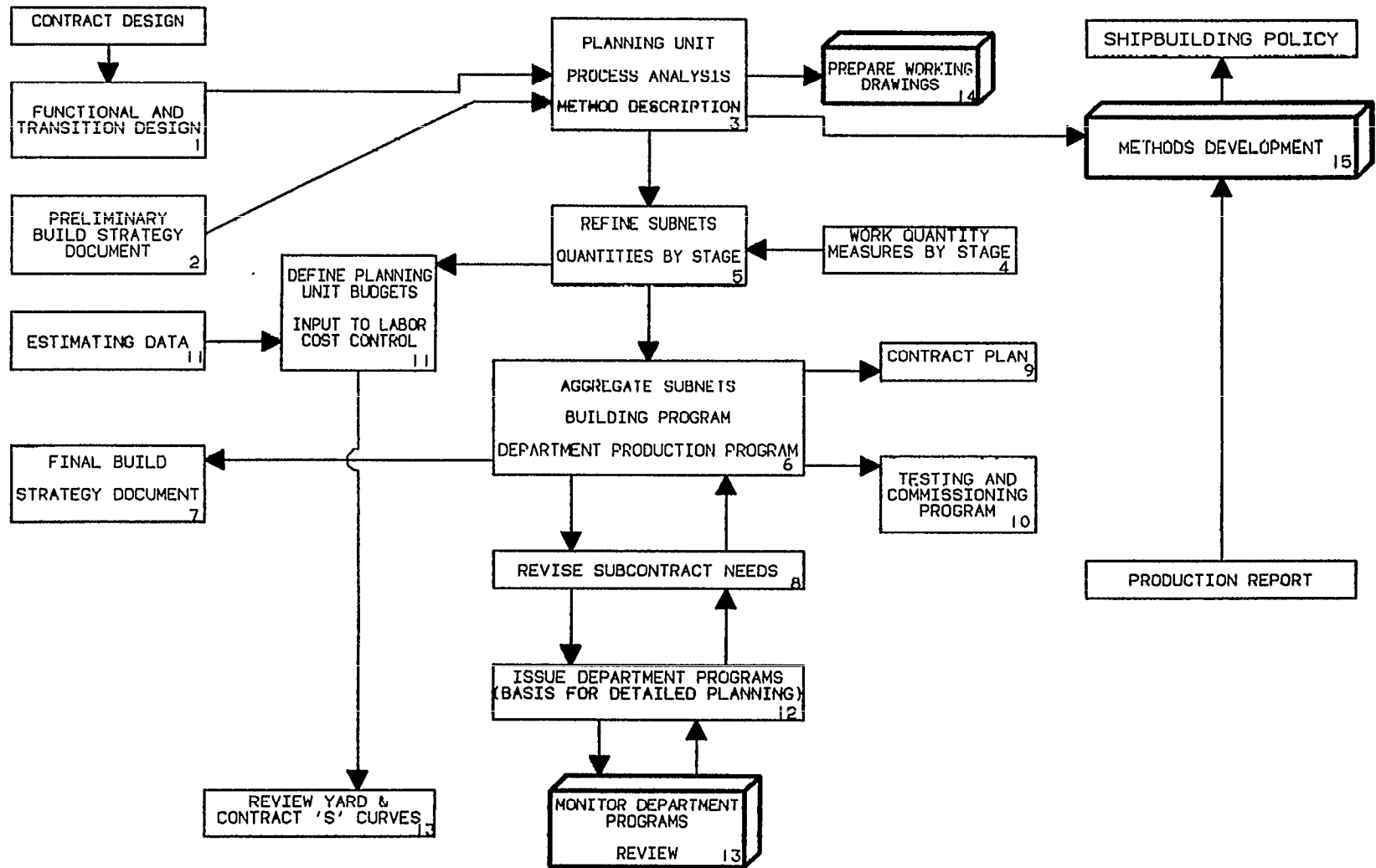
Work station drawings will be prepared by the detail design engineers on the basis of the process analysis work.

### Methods Development (15)

Methods development work is an ongoing activity carried out by production engineers at the tactical level. Information is received from the shop floor on problem areas. These are reviewed and solutions prepared. Similarly, there is an interface between methods development and the company shipbuilding policy. Revisions in the policy may require a review of methods, tools and equipment and vice versa.



## TACTICAL PLANNING



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#### 2. 4. 4     DETAIL PLANNING

This chapter describes the activities carried out at the detail planning level and the links between detail planning and other functions. Detail planning is short term planning with a time horizon of about two weeks.

#### CROSS-REFERENCES

2. 2. 4     Transition Design

2. 2. 5     Detail Design

2. 4. 1     Structure & Organization of Planning

3. 4        Detailed Production Engineering

## 2. 4. 4 DETAIL PLANNING

### 2. 4. 4. 1 Introduction

Detail planning is concerned with the production of detailed programs for each work station in accordance with the requirements of the department production program.

The main steps in detail planning and production engineering are:

Development of two week work station programs balanced against capacity, and preparation and issue of weekly schedules.

Initiation of work (weekly work list).

Progress monitoring and review.

### 2. 4. 4. 2 Tactical Planning Elements

#### work Package Information (1)

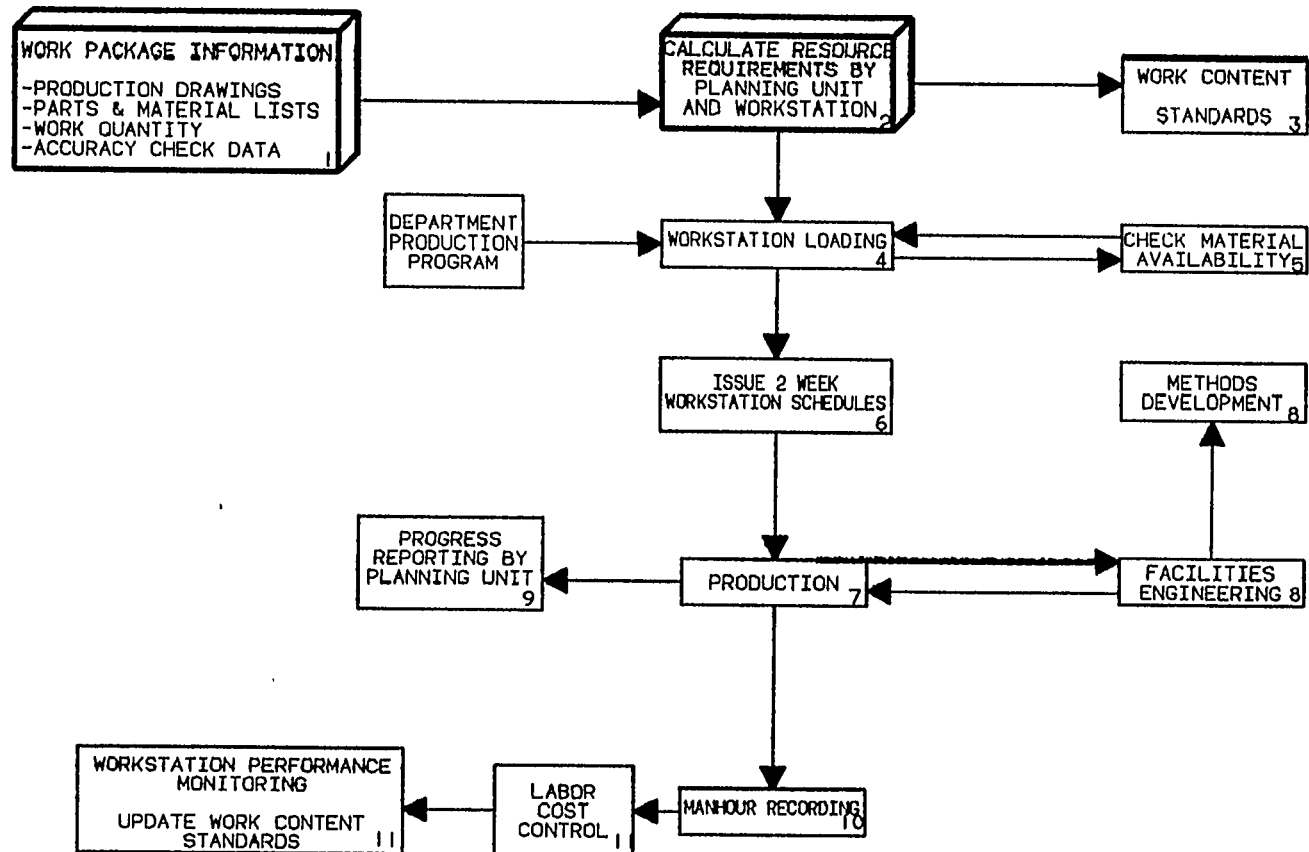
The work station drawing is the basic piece of information required for the completion of any package of work. Other information included with the package will be:

parts and material lists,  
work quantity information,  
requirements for accuracy checking.

#### Calculate Resource Requirements (2)

Resource requirements are calculated by planning unit and work station. The work package information will have details of work quantity, for example; the joint length for fairing, areas for painting, running lengths for lining bulkheads, etc. This data will be used to calculate manhours, machine time and other resource requirements.

## DETAIL PLANNING



**Work Content Standards (3)**

Work content standards will be required to convert the work quantity data held on the work station drawing to work content in terms of machine or manhours. These standards will be reviewed and updated on the basis of actual performance data gathered on the shop floor via the labor cost control system (see 11 ).

**Work Station Loading (4)**

Given the department production program and the work content data, it is necessary to define in detail the work to be done at each work station, over a four week period. This task can be carried out in a number of ways, using bar charts, histograms or a computer based work station loading system. There will be sufficient buffer times built into the department production program to allow shop management and supervision to generate a work station loading to suit their own production requirements.

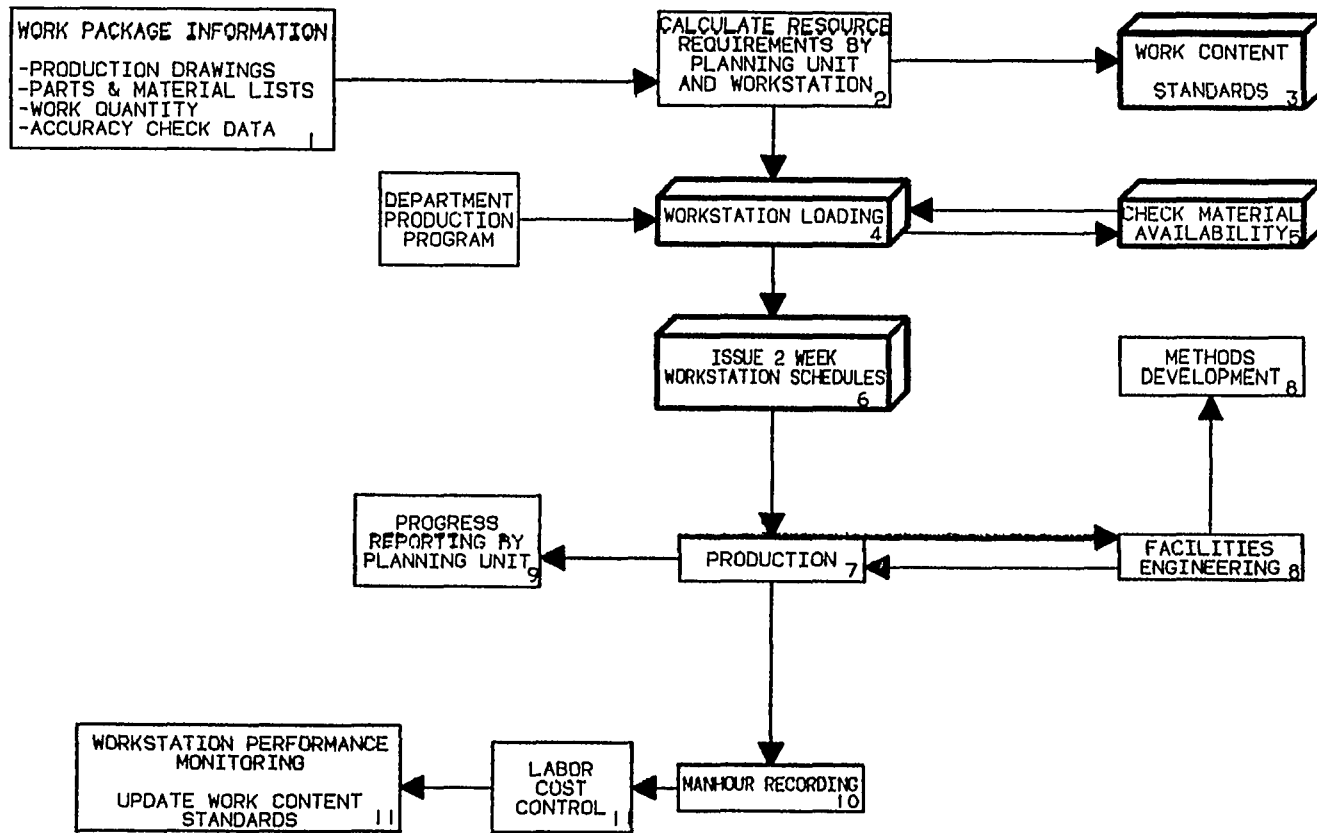
**Check Material Availability (5)**

This is a final check, ideally using a computer based material control system, on the availability and location of materials required in production. If there are shortfalls, early action must be taken.

**Issue Schedules of Work Packages (6)**

The schedule will be issued, or published in a control room on a two week rolling basis. The schedule will be the basis for all production work and supporting material control activities.

## DETAIL PLANNING



### Production (7)

Materials and technical information are moved to the work stations in accordance with the detailed work station schedule.

### Detail Production Engineering (8)

Experience gained on the shop floor must be captured and used to develop improved methods and techniques. This information will only be of value if a consistent approach is taken from one contract to the next in accordance with the process analysis work. Otherwise, this feedback will be random and of little value for the future.

### Progress Reporting (9)

Progress reporting will be against planning units. There need be no emphasis on achieving a certain number of tons per week or other, similar, parameter if planning unit targets are being met.

### Manhour Recording (10)

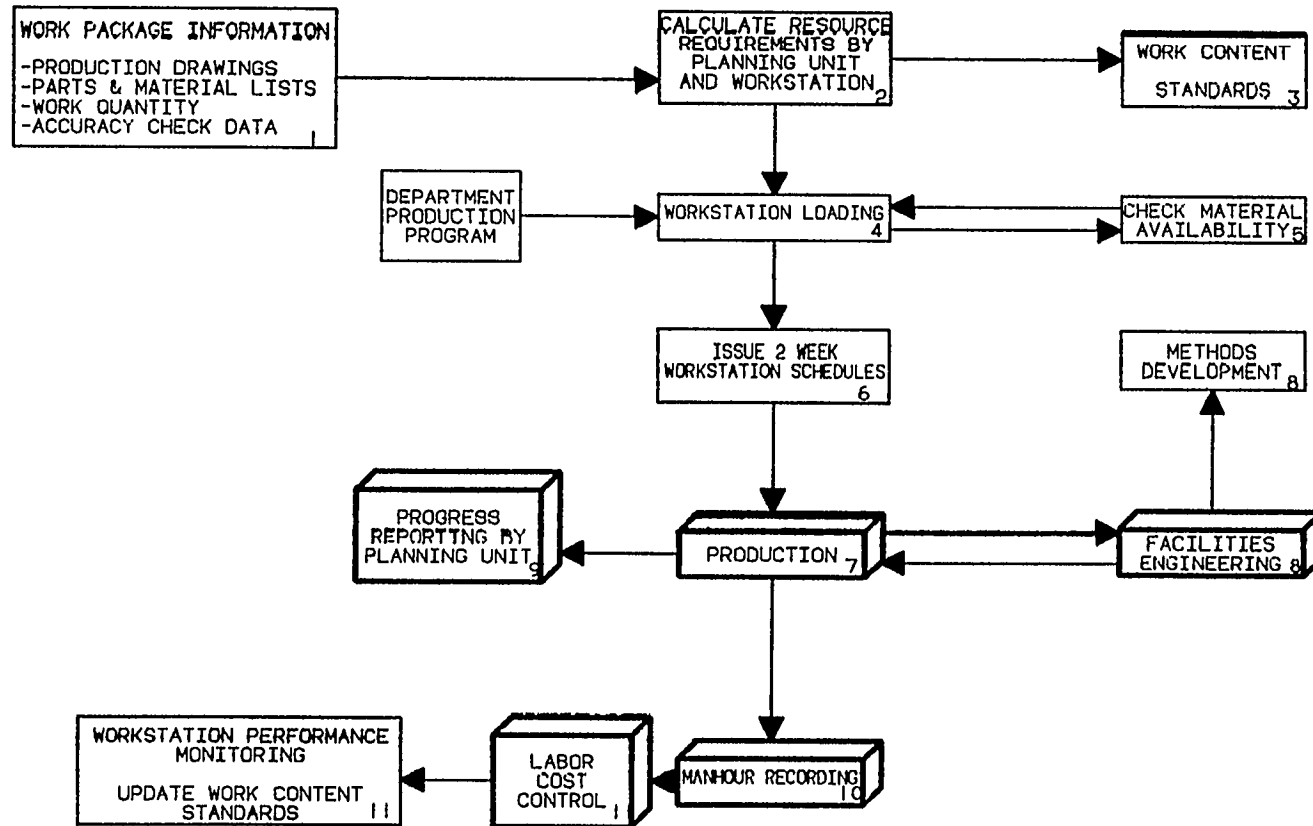
Manhours should be recorded against planning unit, stage and work station. This will enable both planning unit budgets to be monitored and work station performance calculated.

### Labor Cost Control (11)

The labor cost control system will be planning unit oriented. Work content standards will be updated as work done for hours worked is assessed.



## DETAIL PLANNING



#### 2. 4. 4. 3 Summary

Planning procedures are established to provide management, at all levels, with information. It is by using this information that management can establish a coordinated and controlled shipbuilding operation. Using the design for production techniques set out in this manual, it is possible to generate a simple production environment. This environment is characterized by products being manufactured at well defined work stations. The jobbing or "custom" environment must be minimized to the maximum extent possible since, from a planning point of view, the jobbing environment is the most difficult to control. Therefore, on the basis that simple production requires only simple planning, the objective of design for production is to create the simple production environment. All efforts must be concentrated in this direction. Efforts to develop complex planning systems to control a complex production environment are doomed to failure.

GLOS

## GLOSSARY OF TERMS

### Introduction

A number of the terms used in the manual may be unfamiliar. In some cases, they have been given a very specific meaning and in most cases, there is a more detailed description of the term within the body of the manual. However, these detailed descriptions are not repeated in all three volumes and the reader will be able to refer to this glossary for definitions as required.

In some cases, there may be more than one term for a particular process or other aspect of ship production. Where appropriate, alternatives are given.

Because of the diverse nature and widespread location of the industry, it is inevitable that some terms will be used differently by some readers. In these cases, the glossary will help to resolve any problems.

#### ACCESS AND STAGING PLAN

Plan which shows location of temporary access holes, staging clips and attachments, access ways and staging required to facilitate construction.

#### ACCURACY CONTROL (A/C)

The application of various methods of controlling accuracy and dimensions during production by auditing tolerance requirements. A/C emphasizes worker checks as well as improved fitting and welding techniques at appropriate states of production to minimize problems at subsequent stages.

#### ADVANCED OUTFITTING (Also PRE-OUTFITTING)

Process of installing outfit items during assembly rather than during construction of the vessel or after launch,

#### ANALYSIS

Breaking a whole into parts in order to determine its nature.

#### AREA

A division of the production process into similar types of work problems by anything that creates a clearly different work problem which can be grouped:

by product feature (curved vs flat assemblies, steel aluminum structure, small diameter vs. large diameter pipe, etc)

by kind of work (marking, cutting, bending, welding blasting, etc)

by the physical location or facility through which a given type of work is processed (panel shop, pipe shop, etc).

#### ASSEMBLY ANALYSIS

Process of analyzing a planning unit and breaking it into the units, sub-assemblies and pieces from which it will be assembled.

#### ASSEMBLY

Process of joining pieces (steel or outfit) together prior to erection at the ship.

#### AN ASSEMBLY

The product of an assembly process.

The term "assembly" is usually modified to indicate which part of the process, or which element is specifically referred to.

#### ASSEMBLY, OUTFIT

Process, or end product, of joining together outfit items.

#### ASSEMBLY, STEEL

Process, or end product, of joining together steel items.

#### ASSEMBLY, MINOR

Process, or end result, of joining two or more pieces into a product, which will then be joined to other products to form a sub-assembly.

#### ASSEMBLY, SUB

Process, or end result, of joining pieces into an assembly, which will then be joined to other assemblies.

#### ASSEMBLY, UNIT

Process of joining sub-assemblies and pieces to form units.

#### ASSEMBLY, BLOCK

Process of joining units for form blocks.

#### ASSEMBLY LINE

A set of workstations linked by conveyors for the sequential assembly of similar units.

#### B L O C K

An assembly formed by joining two or more steel units. The largest assembly produced away from the erection site.

#### BLOCK BREAKDOWN

The process, or end result, of determining how a vessel will be split into steel blocks.

#### BREAKDOWN, UNIT

The process, or end result, of determining how a vessel will be split into steel units.

#### BUFFER STORAGE

Storage area for the products of a work station before they are transported to the next work station in their assembly sequence.

#### BUILD CYCLE

The time from start of production to delivery for a particular vessel.

#### BUILD PROGRAM

An overall program showing the timing of key events leading up to and during the Build Cycle of a vessel.

#### BUILD STRATEGY, CONTRACT

A document which describes how a vessel is to be built and when key events will take place.



#### CLOSING PIECE (Also MAKE-UP PIECE or CLOSER)

A piece which joins parts of two adjacent assemblies, the dimensions of which are lifted at the ship.

#### COMPUTER DESIGN/COMPUTER AIDED MANUFACTURING (CAD/CAM)

The application of computers to facilitate the design, engineering, lofting and fabrication processes.

#### COMPUTER GENERATED PARTS LIST

A computer generated list of material for a specific end use associated with a drawing. The computer generated parts list provides information pertaining to the material, catalog number, unit scope, function code, trade routing, quantity, etc, of each part,

#### COMPONENT

Any single item which is vendor furnished rather than shipyard manufactured.

#### COMPOSITE DRAWING

A drawing which depicts simultaneously the arrangements of all the individual ship systems within one zone.

#### CONCEPTUAL DESIGN - See DESIGN

#### CONTRACT

Legally binding agreement between two or more persons or parties. In shipbuilding, the contract involves a detailed specification of work and commitment to price and schedule.

#### CONTRACT AWARD

Date on which a customer commits the shipyard to fulfill a negotiated contract.

CONTRACT BUILD PROGRAM - See BUILD PROGRAM

CONTRACT BUILD STRATEGY - See BUILD STRATEGY

#### CONTRACT CYCLE TIME

Time from contract signing to delivery of the finished vessel.

CONTRACT DESIGN - See DESIGN

CONTRACT KEY EVENT PLAN - See KEY EVENT PLAN

#### CONSTRUCTION (Also ERECTION)

The process of installing steel and outfit assemblies to form the vessel at the erection site.

#### CONSTRUCTION CYCLE (Also ERECTION CYCLE)

The time between the start of construction on the construction site and launch.

#### CONSTRUCTION SITE (Also ERECTION SITE)

The shipbuilding berth or dock from where the vessel will be launched.

#### DATUM LINE

A reference from which assembly and installation dimensions are measured. The datum relates to waterlines, buttocks or hull stations rather than structure.

#### DEFINITION, SHIP

Output of, or process of, design.

#### DESIGN

Process of defining the specification or relationship of any part of a vessel. Divided into stages.

#### DESIGN, CONCEPTUAL

The establishment of the overall features of a design to meet mission requirements.

#### DESIGN, CONTRACT

The establishment of the features of a design sufficient to provide the basis of a contractual arrangement.

#### DESIGN, FUNCTIONAL

The establishment of the functional features of a design for the purpose of classification and other approval and complete material specification.

#### DESIGN, TRANSITION

The translation of the features of a design from the system orientation necessary to establish functional performance to a planning unit orientation necessary to establish production requirements.

#### DESIGN, DETAIL

The establishment of the features of a design in sufficient detail to allow local purchasing, part manufacturing and subsequent assembly and installation to be carried out.

#### DESIGN AGENT

Company or group of companies providing a design service and providing engineering, drawings and production information to a shipyard.

#### DESIGNER

Any person engaged at any stage of the design process.

#### DESIGN LEAD TIME

The time, nominally between contract award and start of production, available to designers to meet scheduled requirements.

#### DETAIL PLANNING - See PLANNING

#### DIAGRAM

Representation of a ship system showing the system function but not its location on the vessel.

## DRAWING

Pictorial representation of all or any part of a vessel, including specification and production information.

## DRAWING, WORK STATION

A drawing which relates to a work package to be carried out at a specific work station. Includes production information

## ENVELOPE

A volume which is sufficient to contain parts of a ship system, or systems, and which can be used to define the location of those parts at the preliminary design stage.

ERECTION - See CONSTRUCTION

ERECTION CYCLE - See CONSTRUCTION CYCLE

ERECTION SCHEDULE (Also CONSTRUCTION SCHEDULE)

The timed sequence in which the steel planning units will be installed at the erection site.

ERECTION SEQUENCE (Also CONSTRUCTION SEQUENCE)

The sequence in which the steel planning units will be installed at the erection *site*.

ERECTION SITE - See CONSTRUCTION SITE

#### FABRICATION (Also PREPARATION)

The initial production process consisting of layout, cutting and forming to create outfit or structural piece parts.

#### FACILITIES

The buildings, cranes, plant and equipment available to a shipbuilder.

#### FAMILY

A set of parts or assemblies related by geometry and specification, which can be produced by the same work stations.

#### FUNCTIONAL DESIGN - See DESIGN

#### FUNCTIONAL SPACE

A volumetric envelope on a vessel which contains related items from one or more ship systems and which is dedicated to a specialized aspect of vessel operation.

## GROUP TECHNOLOGY

A basis for production organization which allows small batch and one-of-a-kind production to gain the benefits normally obtained from flow production of large numbers of products.

## GROUP - See PROCESS LANE

In group technology, a set of related production facilities applied to one or more families of products.



## HOUSEKEEPING

The tidiness and cleanliness of facilities. Housekeeping is one indicator of the quality of production organization.

## INDUSTRIAL ENGINEERING (ALSO PRODUCTION ENGINEERING)

The application of systematic methods to determine the requirements of production and to develop a production system to meet those requirements. This includes the integration of Design and Production.

## INSTALLATION ANALYSIS

Analysis of the zones on a vessel to determine at what stage of production the installation of various outfit items should take place.

## INSTALLATION

The process of adding outfit items to the vessel, either after launch or at the construction site.

The process of adding outfit items to the steelwork of the vessel during the assembly stages. See also ADVANCED OUTFITTING.

## INTERIM PRODUCT

Any part or assembly which is the output of a workstation, is complete in itself and the completion of which can be used as a measure of progress.

#### KEY EVENT PROGRAM

A program which shows the most significant events between the contract award and delivery of a vessel.

#### KEY PLAN

A plan showing the steelwork arrangement of all or part of a vessel on which outfit systems are located.

## LEAD TIME

The time between an event and another related event, during which all preparation for the second event must take place.

LEAD TIME, DESIGN - See DESIGN

## MARSHALLING

**The collection of parts,** components and assemblies into sets which meet the requirements of the next production stage.

## MATERIAL CONTROL

The process of determining how materials should be marshaled and subsequently controlled to ensure the intentions are complied with.

MINOR ASSEMBLY See ASSEMBLY

## MINOR STEEL

Non-structural steel parts and assemblies. Usually Produced in the shipyard and usually related to outfitting;

## MODULE

An outfit assembly consisting of functionally related components and connecting parts mounted on a steel frame and completed prior to installation. Especially in machinery spaces.

## NETWORK

The representation of a set of logically connected events, or activities, which shows the sequence and inter-dependence of those events or activities.

### NETWORK, SUB

A detailed network showing the sequence and dependence of events or activities leading to one particular event or activity on an overall network.

ON FLOW, of products

Term indicating that a product belongs to a family and is compatible with-a work station or group of work stations.

OFF FLOW, of products

Term indicating that a product does not belong to a family and therefore requires non-standard production processes.

OUTFIT UNIT

An assembly of predominantly outfit items which is assembled off the vessel and then installed in one lift onto the hull structure.

## P A N E L

An assembly of flat plates, butt joined, together with associated stiffening.

PART - See PIECE PART

## PARTS LIST

A list of all items required to complete a particular work package.

## P H A S E

A step in the assembly or installation process. The work in a phase constitutes a work package.

## PIECE PART

Product of the fabrication stage of production. An item made in the shipyard.

## PIPE BANK

An outfit assembly comprising pipes from one or more ship systems, mounted on supports and completed prior to installation.

## P L A N N I N G

Process of determining the sequence of events in design production and other shipyard functions, in advance of those events occurring.

## PLANNING, STRATEGIC

Long term planning, beyond the current order book and generally over a timescale of several years.



#### PLANNING, TACTICAL

Medium term planning with a time horizon of about three months. The preparation of an overall program for each contract and a corresponding program for each department.

#### PLANNING, DETAIL

Short term planning with a time horizon of about two weeks. Planning of events at individual work stations.

#### PLANNING UNIT

A steel block (or pair of blocks) large outfit assembly or installation zone, the completion of which is an event at the strategic planning level. The planning unit is the basis for more detailed planning and engineering activity.

#### POLICY, COMPANY

A statement of the way in which a company plans to meet its overall business objectives.

#### POLICY, SHIPBUILDING

A statement of the way in which the technical and manufacturing functions in a shipyard plan to carry out company policy.

#### PRELIMINARY DESIGN - See DESIGN

#### PRE-OUTFITTING (Also ADVANCED OUTFITTING)

Installation of outfit items on structural assemblies prior to unit of block erection.

#### PREPARATION - See FABRICATION

## PROCESS ANALYSIS

Determination and evaluation of the proposed sequence of events leading to completion of an assembly.

## PROCESS LANE - See GROUP

A group of work stations designed to produce a family or families of products which require similar processes.

## PRODUCIBILITY

An attribute of a design or product which allows it to be manufactured effectively with the available facilities.

## PRODUCT, INTERIM - See INTERIM PRODUCT

## PRODUCT DEVELOPMENT

Process of determining the types and sizes of vessels to be built by a shipyard, and the preparation of conceptual designs.

## PRODUCT WORK BREAKDOWN STRUCTURE (PWBS)

The application of Group Technology to subdivide work into logical production categories. These categories organize shipbuilding into discrete products which are used to plan and control production.

## PRODUCTION

Any aspect of the process of making a vessel, or of the crafts and facilities directly associated with that process.

## PRODUCTION ENGINEERING - See INDUSTRIAL ENGINEERING

#### PRODUCTION INFORMATION

Any information which informs production how or when to carry out their function.

#### PRODUCTION STAGE

A particular phase of the ship production process.

#### PRODUCTIVITY

The ratio of output to input. Often expressed as a quantity of work achieved for given expenditure of manhours.

## RAW MATERIAL

Material bought by the shipyard in made or processed form which can be converted into useful products.

## SCHEDULE

A list of tasks to be performed or items to be completed with the associated dates by which they are to be completed

## SCHEMATIC

A single line drawing showing (non-geometrically) items of equipment and individual inter-connections.

SHIPBUILDING POLICY - See POLICY

## SHIP DEFINITION

Output of, or process of, design.

## SLICE

Part of a vessel between two transverse planes. Output of the first stage of unit breakdown.

## SPATIAL ANALYSIS

The process of defining at the preliminary design stage, a vessel's internal layout as a series of envelopes.

## STAGE

A particular phase of the design or production process.

## STAGING

Upright supports and working platforms giving access to a vessel during construction.

## STANDARD

An established model or example which can be broken down according to basic types of information. Some types of standards typically encountered are as follows: -

Design Standards - Engineering/Design data on how to perform calculations, develop a design, etc.

Application Standards - Defined service applicability of components.

Material Standards - Dimensional data for individual components which may be used for fabrication purposes.

Performance Standards - Defined minimum acceptable criteria for performance.

Standard Drawings - Standard design configurations to aid engineers and designers and to reduce design time.

Standard Procedures - Established or prescribed methods to be followed routinely for the performance of designated operations such as planning, scheduling and budgeting.

STRATEGIC PLANNING - See PLANNING

SUB ASSEMBLY - See ASSEMBLY

SUB NETWORK- See NETWORK

## SYSTEM

Any set of objects or activities inter-related to form a coherent whole.

## SYSTEM, SHIP

Set of equipment and inter-connecting service runs which carry out a particular function in the finished vessel.

## SYSTEMS

Inter-related activities which organize and control the operations of a shipyard.

TACTICAL            PLANNING - See PLANNING

TECHNICAL

Functions of shipbuilding related to design and development of production information.

TRANSIT ROUTE

A pre-determined volume which will provide a route for services on the vessel.

TRANSITION DESIGN - See DESIGN

TYPE PLAN

A program showing the sequence of completion of planning units for a vessel type, independent of timescale.



UNIT (Also STEEL UNIT and OUTFIT UNIT)

An assembly forming part of the vessel which will be taken to the construction site to be joined to the hull.

UNIT ASSEMBLY - See ASSEMBLY

UNIT BREAKDOWN- See BREAKDOWN

**VENDOR FURNISHED**

Any information or item supplied by an external source to the shipyard.

**WORK AREA**

Any part of the production facilities with a specific function. Any group of related work stations.

**WORK BREAKDOWN STRUCTURE**

Any method of classifying the tasks involved in a construction project into systematic groupings.

**WORK CONTENT**

The quantity of work in a job. Can be converted to manhours by applying a productivity ratio.

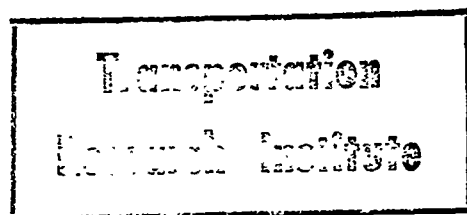
**WORK PACKAGE**

A given task involving a discrete quantity of material or time.

**WORK STATION**

The physical space or location where a particular type of work is performed. A work station can vary in size and location depending on the type of work involved.

The work station concept is a direct application of group technology, where similar types of work are performed in the same locations allowing for an efficient allocation of workers, time, tools and material.

**WORK STATION DRAWING - See DRAWING**

## Z O N E

A defined geographical sub-division of a ship.

### ZONE , PRIMARY

The initial division of a ship into functionally related spaces. Machinery space, cargo space, accommodation space, etc.